Journal
of the
British Interplanetary Society

Vol. 10, No. 5 **XLII** **September, 1951**

B.I.S. or I.S.?

The suggestion from Dr. Martyn, F.R.S., that the B.I.S. should change its name to "The Interplanetary Society" (see *Journal*, March, 1951) has resulted in a considerable correspondence from our membership. About 85 per cent. of those writing were in favour of the proposed change, some of the reasons supporting it being as follows:—it is the simplest title: the word "British" is incongruous in such a context: a large proportion (one-sixth) of our membership is *not* British and the adjective may act as a deterrent to foreign members.

Two members suggested alternative titles: one complained that the word "interplanetary" was still inclined to produce a certain amount of derision, and proposed that we should call ourselves the "British Astronautical Society." In reply to this suggestion we would point out that the premise is no longer true: "interplanetary" has long ceased to be a signal for raised eyebrows, and the alternative "astronautical" is still largely unknown and might cause confusion with the astronomical and aeronautical societies.

Yet another suggestion was "The Institute of Space Travel"—on the grounds that, it is hoped, we should not always be restricted to the planets! This argument, however, hardly carries much weight as the word "interplanetary" does not specify the planets of any particular sun!

To return to the main theme—the choice between "B.I.S." and "I.S."—despite the arguments put forward the Council is against such a change. The reasons for our opposition were stated at the Extraordinary General Meeting on 26th May, 1951, when, after the official business of approving the increased subscription rates, an opportunity was taken of dealing with any other matters which the meeting could consider. The arguments against any change were explained by our Chairman, and after some discussion the meeting as a whole voted 90 per cent. *in favour of retaining our present name*—a complete reversal of the situation as shown by the postal response! (It might also be remarked that rather more members were present at the meeting than gave their views by correspondence.)

We believe that when the membership as a whole hears the reasons for opposing any change in title it will agree with the Council that, even if there may be some theoretical advantages in assuming the name "The Interplanetary Society," the time is not opportune to do so.

As for the suggested advantages, we feel that as a matter of purely practical convenience it is desirable for an association such as ours to have the name of its headquarters' country in its title—however internationally-minded it may be. Of the 16 societies listed in the 1950 Annual Report, 13 had geographical

labels. This seems to us a convenient state of affairs, and there is really nothing incongruous about it.

The main argument, however, against any change at the present time is the forthcoming International Congress on Astronautics. We feel that any change in the name of our society would be inadvisable—perhaps even tactless—when we are endeavouring to form a federation of societies from all parts of the world.

We hope that "The Interplanetary Society," in fact if not in name, may soon come into existence, being the world-wide complex of all societies working towards our common goal. Our views are, indeed, well summed up in a letter from one of our overseas members, who writes as follows:—

> "What, in fact, is the Interplanetary Society? It is the body of people all over the world who have a vision of the coming of interplanetary communication, and who are concerned with preparing for, and perhaps participating in, its realization. The Interplanetary Society might be more clearly recognized, and its international character protected from the potential danger of the appropriation of its title, if the various national interplanetary societies agreed to the formation of a society to be called 'The Interplanetary Society.' Membership of the society would, it is proposed, be open only to societies approved by a majority of the societies represented at the International Astronautical Conference.
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> "If such a move were practicable, would it not correspond quite closely with the idea expressed by the B.I.S. at the last conference for a not too rigorous 'form of federation of autonomous national societies'?"

We believe that it would—and we hope that it will.

APPLICATION OF THE GENERAL TRAJECTORY EQUATIONS

By George F. Forbes

Summary

This paper is an extension of a previous paper.[1] Emphasis is placed on the applicability of the mathematics to the problem of moving a close-in satellite craft into an interplanetary orbit without the use of a high thrust motor.

Notation

A'	time rate of sweeping of area by radius vector.
a	acceleration due to rocket motor thrust.
h	$= \tan \psi$ angle between radius vector and path.
K	(mass of attracting body) $\times$ (universal gravity constant).
K_d	dimensional constant to suit.
γ	convenience variable ($\gamma = a/s'$).
ρ	polar co-ordinate radius.
S'	linear velocity.
T	total trip time.

Remarks Concerning the Previous Paper

The reference contains two errors, one minor and one of some importance. On page 76, 1·1121 should be numbered 2·1121. The velocity change for the spiral and elliptical orbits given on page 77 was not specified to be an approximation for a comparison to a quarter ellipse.

With respect to the basic equations, (2·1121 and 2·1212), all trajectories for which the motor thrust is along the path (in either direction) will satisfy the equations and also:

$$(2\cdot126) \qquad \gamma = A''/A' = a/S'$$

Conversely, any trajectory which does not satisfy the equations (2·1121 and (2·1212) will not be due to a tangential motor thrust. In other words, the mathematics covers all cases of efficient use of continuous motor power (including coasting).

Another Equation

The following equation, which was not shown in the previous paper, is of considerable value:

$$(2\cdot133) \qquad \frac{d\rho}{\rho} + \frac{dh}{h(1+h^2)} - \frac{K d\rho}{\rho^2 S'^2} = 0$$

It is mathematically obvious that this equation presents a solution for all trajectories for which $S'^2 = K_d f(\rho)$. For these trajectories the equation is integrable and will present the trajectory as an h,ρ relationship. K_d is a dimensional constant and will be suited to $f(\rho)$.

For the case $S' = \sqrt{K/\rho_1}$ the time may be estimated by estimating the path length although a rather involved definite integral is available giving T as a function of the initial and final ρ. The acceleration law is rather simple, being:

$$(81\cdot44) \qquad a = \frac{K \cos\psi}{\rho^2}$$

The trajectory itself is somewhat more complex, being:

$$(81\cdot12) \qquad \frac{\rho \sin\psi}{\rho_1 \sin\psi_1} = e\left(1 - \frac{\rho_1}{\rho}\right)$$

With some mathematical ingenuity and some rather involved algebra, solutions may be worked out for other cases, and in spite of the rather tedious work, the resulting trajectories might prove to be of some value.

Application to the Satellite Craft

The importance of equation (81·12) and similarly derived equations lie in their applicability to a circular orbit as an initial condition. This possibility does not exist in the logarithmic or orbit-matching spiral.

By adjusting the final conditions of a departure trajectory such as (81·12) to match the initial conditions of a conic, logarithmic spiral, or orbit-matching

spiral trajectory; it should be possible to bring a close-in satellite into an interplanetary trajectory. The present state of the mathematics indicates it would be necessary to hold the departure orbit until the earth's attraction became small enough to permit compensating for it by a component of the satellite's thrust. This would also be true, of course, for the moon's effect.

Predictions

Several remarks can be made concerning interplanetary craft which may seem somewhat sweeping. The remarks are based on the mathematics rather than any specific proposed craft. They presuppose the assumption that high total (propulsive and internal energy) mass efficiency in a motor will be accompanied by a very low thrust and continuous operation.

1. A space craft, once in a satellite orbit, does not need a high thrust intermittent motor for any but emergency use. A motor thrust producing 0·01 g. in free flight would be adequate, and thrust producing as little as 0·0001 g. would be usable.

2. A low thrust motor and fuel could easily be equivalent to many times its weight in high thrust motor fuel. Once in free flight, 0·01 g. for 100 minutes is as effective as 1 g. for 1 minute. (Assuming, of course, that rapid changes in speed or direction are not essential.)

3. Interplanetary flight will be practical and possible when a large satellite craft can be built in a close-in orbit about the earth, and when this craft can be supplied with a suitable low thrust motor. From an engineering point of view, such a motor is probably feasible at the present time.

4. The mathematics involved in powered trajectories need be no more involved than that for the conic orbits.

5. Because of the possibility of continuous corrections, as in ocean navigation by aircraft, the problem of trajectory stability will not be serious.

6. Optical instruments measuring apparent diameter and angle and a chronometer should be sufficient for space navigation.

7. Slide rule computations and slide rule accuracy should be sufficient for any normal navigation needs. For certain orbits tables might prove useful.

8. Although the tangential ellipse is undoubtedly the trajectory requiring the least thrust-time,[2] the advantages of a low thrust motor could easily outweigh that factor.

REFERENCES

(1) G. F. Forbes, "The Trajectory of a Powered Rocket in Space," *B.I.S. Jnl.*, **9**, No. 2, March, 1950.

(2) "Notes on a paper by G. F. Forbes," by D. F. Lawden, *B.I.S. Jnl.*, **9**, No. 5, Sept., 1950.

THE AIR OF OTHER WORLDS

By V. A. Firsoff, M.A.

Introduction

The study of the atmospheres surrounding the planets and their satellites derives its great interest from two considerations. They are the only parts of our neighbour worlds whose chemical composition we may hope to determine with any certainty. Their structure and nature have varied implications for the estimated conditions on the planets' surfaces and for the probability or otherwise of life on them. Our knowledge of life is, of course, limited to the terrestrial situation, and the possibility of entirely different biological schemes cannot be lightly dismissed.[4] For all we know some forms of life may flourish in total absence of atmospheric gases, but in the present state of our knowledge this appears unlikely.

However, the subject is so vast and has so many ramifications that I can do no more than touch lightly on its most important aspects.

Atmosphere Detection

There are various ways of detecting the presence of an atmosphere around a heavenly body which shines by reflected light.[3,5] A high albedo may be taken as an indication of a gaseous envelope, though too much importance cannot be attached to this, as the planetoid Vesta, which, barring an absurdly high density, could not possibly retain an atmosphere, has an albedo comparable to that of Venus.[7] Also, any marked departure in colouring from the "neutral" greys or browns of rock is more often than not due to the presence of gas, in the past if not now. A deep gaseous layer will cause the edge or limb of the disc to appear darker than the centre. When observed in twilight Jupiter and Saturn display this haziness of the limb even in a small instrument. Yet this is not necessarily so, and a clear atmosphere, strongly scattering sunlight, may produce the exactly opposite effect, so that the planet's disc looks brighter round the edges, as is the case of Venus and Mars, whose terminator, however, visible in the gibbous phase (being an exterior planet, Mars can never exhibit the "half-moon" or crescent phase), has a hazy outline. The latter is due to the so-called "twilight arc," that is to say, the part of the globe where the sunlight dispersed in the atmosphere encroaches on the unilluminated half. In the crescent phase, which can be observed only on the Moon and the interior planets, Mercury and Venus, the twilight may cause an extension of the cusps or "horns" of the crescent beyond their geometrical boundary. On Venus the effect is so marked that when the crescent is very narrow (high "phase angle") a thin line of light, the so-called "silk thread," has been observed running right round the night hemisphere. The phenomenon was particularly noticeable on 2nd December, 1898, and 29th November, 1906,[3] on which dates the atmosphere of Venus near the terminator must have been clearer than usual, so that we could see down to greater depths, normally obscured by clouds.

The twilight arc can be measured, and from it the height of that part of the atmosphere which is sufficiently dense for producing observable scattering

of sunlight can be determined. In estimating such measurements we must, however, bear in mind that on Earth the extension of the twilight arc can be followed much farther than it can be on another planet, and the thickness of a planetary atmosphere obtained in this way is invariably too low.[7] Haze, clouds, snow, hoar-frost or seasonal changes in the colouring and appearance of surface markings are all indications of a gaseous envelope.

Occasionally the planet in its apparent motion in the sky comes between us and a bright star, which is eclipsed or "occulted." If the planet has a negligible atmosphere (less than 1/1,000th of the density of our air) or no atmosphere at all, the star, which is a point of light of no measurable width, will disappear instantaneously when contacting the limb of the planet and reappear as suddenly at the end of the occultation, whose duration will be neither more nor less than that obtained theoretically from geometrical considerations. If, on the other hand, the occulting body has a reasonably dense atmosphere, the light from the star will fade out gradually, it will remain visible owing to refraction for a while after it has been covered by the dark disk, and reappear at the end of the occultation a little earlier then geometry would warrant. These observations can give us valuable information regarding the depth and density of the studied atmosphere, but have proved ineffective in the case of extremely rarefied gaseous envelopes, such as surround Mercury and the Moon.

Mercury and Venus, being between us and the Sun, occasionally cross its disk. This is a kind of "unsuccessful eclipse" and can happen only when the planet is near one or the other of the nodes of its orbit, i.e., the points where this intersects the Ecliptic, or the apparent path of the Sun in the sky. Transits of Mercury, which is closer to the Sun, are the more frequent and occur at intervals of 7 and 13 years. Those of Venus are much rarer and come in pairs (divided by an interval of 8 years) about 105 years apart. Just shortly before the inkspot of the planet touches the disk of the Sun or breaks off apparent contact with it, Venus appears surrounded by a fiery ring, due to refraction in her atmosphere. She also seems to stretch towards the Sun as though an "ink drop" were forming between them. Mercury shows no comparable refraction ring, although a faint wide halo, ascribed to irradiation, has occasionally been seen.[14]

From the width of the ring a very rough estimate of the depth of the refracting atmosphere can be made, but the glare of the Sun allows us to see only the brightest part of the ring and a considerable correction is required.

Generally, gas scatters short-wave radiations more effectively than the less refrangible part of the spectrum; in other words, it appears blue, like our sky, while the planet seen through it is reddened. Here it may not be without interest to note that the examination of the intensity of the different parts of the spectrum of Mars made by G. P. Kuiper shows, I think conclusively, that the apparent redness of the planet is largely an atmospheric phenomenon. In any case, the so-called "red" areas of Mars reflect light much in the same way as certain kinds of brown felsite (micro-crystalline trap rock) and are not at all like the Painted Desert of Arizona.[5]

However this may be, a photograph taken through an ultra-violet filter

will reveal primarily the atmosphere which reflects strongly in this region; while an infra-red exposure will show mainly the solid surface of the planet (assuming that this is visible).[13]

The polarization of sunlight reflected from the surface of a dark body in relation to phase provides a very sensitive test of the presence of gas above it. Furthermore, the so-called reciprocity principle, according to which the surface brightness at two points of the planetary disk which lie in the same latitude, but where the angles of incidence and reflection are reversed should, if the atmosphere is homogeneous, be proportional to the cosines of the angles of incidence, allows us to detect invisible air currents. In this way, Minnaert has been able to find strong convection streams near the terminator of Venus[5] (which, incidentally, may be masking the rotation of the planet in spectroscopic observations).

Indirectly, a gaseous envelope can be inferred from temperature measurements by means of a bolometer, thermocouple, Cashman cell or other similar instrument. As a generally poor absorber of radiation, gas will be colder than a solid surface exposed to the same insolation (there are some exceptions to this rule). On the other hand, through conduction and convection, it will tend to temper the disparity of temperatures between different parts of the globe and between the night and day hemispheres in particular. Here Venus provides a striking example, as even her high atmospheric layers are warmer at night-time than our own air is in broad daylight at a comparable altitude.[7] On the Moon, on the other hand, the temperature of the ground has been observed to fall by 150° C. in a single hour during a lunar eclipse.[12]

An atmosphere, especially when it is rich in carbon dioxide, will also act as a "sun-trap," for it absorbs the "obscure heat" waves (low infra-red) radiated by the ground, thus guarding its warmth against dissipation into space during the sunless hours. This is the famous "greenhouse effect." If, therefore, a planet's observed temperature is higher than its theoretical mean temperature computed from Stefan's law and corrected for "greyness" (the opposite of albedo), this is an almost certain indication of a substantial atmosphere. As a rule, however, this will be no news, for such a gaseous envelope will already have been discovered by other methods. Moreover, the temperature of the surface of an air-covered body is itself very difficult to determine and subject to multiple error. To begin with, our air is transparent only to a narrow range of the low infra-red and the intensity of the missing radiations must be inferred from theory (Planck's formula), which is not wholly satisfactory. Planetary radiations do not necessarily come from the ground and may originate at various levels of the superincumbent atmosphere, the combined effect alone being directly accessible. Thus, if we were able to make radiometric observations of the Earth from, say, Mars, this method would give us a temperature representative of the upper cloud layers rather than her surface.

The theory of gases also gives the astronomer a helping hand in deciding whether a heavenly body is likely or not to possess a gaseous envelope. This depends on the velocity of escape from it and the maximum temperatures it attains. The mean velocity of the molecules of a gas is inversely proportional to the square root of its molecular weight and increases directly with its absolute

temperature. The real velocity of individual molecules, however, is the result of chance collisions with other molecules and may exceed the velocity of escape even when the temperature is low; but the probability of such a happening rises together with the thermometer, and if a certain safety margin is overstepped the whole atmosphere will be lost, molecule by molecule, within a measurable time. Sir James Jeans has calculated that if the mean molecular velocity of a gas is one-fourth of the velocity of escape, an atmosphere composed of this gas will be almost completely dissipated in 50,000 years. But should the mean molecular velocity drop to one-fifth of the parabolic, the life of the atmosphere will jump up to 25 billion years.[8] The critical value will, accordingly, lie somewhere between these two limits.

The complexity of atmospheric structure revealed by modern high-altitude research, the effects of stratification and photo-dissociation, as well as the differences of density gradient, cloud formation, etc., considerably reduce the practical usefulness of such calculations in estimating the life of a planetary atmosphere. Still, the principle is sound enough, and, guided by it, G. P. Kuiper, probably the greatest living authority on this subject, has compiled a list of planets and satellites in the order of declining ability to retain an atmospheric cover. This reads: Jupiter, Saturn, Neptune, Uranus, Pluto (location uncertain in view of the doubtful mass), Earth, Venus, Triton, Mars, Titan, Ganymede, Io, Callisto, Europa, Mercury, Moon, etc.[5] Since both Mercury and the Moon have been found to possess attenuated gaseous shells, it is virtually certain that all the bodies listed here have at least an atmosphere of a kind, even if this has not been discovered to date. Venus, however, would seem to have a more extensive atmosphere than the Earth, although she is listed below our planet, and for that matter the atmosphere of Saturn is deeper than that of Jupiter, so that the list must be taken, to use a B.I.S. phrase, "with a few molecules of sodium chloride."

Very much will depend on the past history of the body in question, and this is purely conjectural. If at any time the body had a high surface temperature it will, except in the case of the major planets, have lost its original atmosphere, and, indeed, the present gaseous envelopes of the terrestrial planets are usually regarded as being of secondary volcanic origin. The satellites of the giant planets may have acquired theirs in a different fashion (so far only on Titan has the presence of an atmosphere been definitely established).[5,8]

Spectroscopic Observations

Theoretical considerations apart, all these observations can teach us little about the actual composition of an inaccessible atmosphere, and in order to explore this we must have recourse to spectroscopy.

This is based on the principle that a gas absorbs from a uniform continuous radiation the emissions of the same wavelengths as it would radiate in the same state of ionization and molecular aggregation, if excited to shine. Thus, its presence and approximate amount can be detected from the absorption lines in the spectrum of the reflected sunlight produced by means of prisms or diffraction gratings.

Things would be simple enough if neither Sun nor Earth had atmospheres of their own, but they have, and consequently the solar spectrum shows a multitude of dark Fraunhofer lines, those of terrestrial origin being called telluric. Instead of a clear document we get a sort of palimpsest, where three messages have been written on top of one another. The Sun does not cause much trouble, but the Earth does, for the likelihood is that the other planets will have round them at least some of the gases found in our air.

The large planets, Jupiter, Saturn, Uranus and Neptune, are enwrapped in voluminous atmospheres largely composed of methane (CH_4) and ammonia (NH_3), which, fortunately—for both are poisonous—do not occur in our air in any quantity. They are, of course, desirable rocket fuels and may some day prove useful in this way. However, the absorption bands of these gases jump to the eye without much ado. The dark gashes due to ammonia are strongest in the spectrum of Jupiter and progressively decline as we move up the series; methane behaves in the opposite way, which is explained by the gradual freezing-out of ammonia as the temperature of the outer atmosphere drops with increasing distance from the Sun, so that we can look deeper and deeper into the underlying methane ocean, which itself is probably viewed through a thick layer of hydrogen and helium.[5]

When overlap with telluric absorptions occurs or is suspected, the situation is much more tricky. There are two ways of tackling it, neither of them completely satisfactory.

One is to compare the spectrogram (photograph of spectrum) of the planet with that of the Moon taken at the same altitude above the horizon, with equal exposure and under similar meteorological conditions. Since the Moon shows no recognizable absorptions and the solar and telluric lines are the same in both cases, whatever is extra belongs to the planet. Yet one can never be quite certain that the atmospheric conditions have been identical in both cases, and the determination of differences in the intensity of the overlapping absorptions is itself open to error.

The alternative method is to observe the planet spectroscopically at a time when its velocity relative to the Earth is high. This causes the planetary absorptions to be displaced by the Doppler shift with regard to their terrestrial opposite numbers. The orbital velocities of the Earth and planets do not, however, differ sufficiently to produce complete separation of their respective absorptions; all that happens is a small but measurable displacement of the centre of density of the compounded lines, which can be determined by means of a sensitive photometer. This test is more delicate than comparison with the Moon, but not sufficiently so for exact measurement of the amounts of oxygen and water vapour in the atmosphere of Mars, which both seem pretty scarce. The first procedure employed by Adams and Dunham, of Mount Wilson, gives the oxygen content of the Martian atmosphere as about 5 per cent. of the terrestrial; the second sets an even lower maximum limit of 0·0015 of the amount present in our air.[5] Yet it must be borne in mind that the light which reaches the spectroscope from Mars is not necessarily reflected from his surface; indeed, most of it comes from the clouds, mists and gas itself at various levels. It is true that the latter reflects mainly in the short-wave region, while

the A and B Faunhofer lines caused by oxygen lie in the red; but some correction remains necessary, for comparison is made with the entire column of terrestrial air in the observer's line of vision, so that such upper limits are not all that they are often imagined to be.

The test for water vapour is not so sensitive and the fact that this is concentrated mainly in the lower portions of any atmosphere[4] makes the objection even more pertinent. The absorption bands due to it are situated in the infra-red. However, in 1948, Kuiper succeeded in tracing weak absorptions of water ice in the spectrum of the polar caps of Mars. He, therefore, concludes "*that the Mars polar caps are not composed of CO_2 and are almost certainly composed of H_2O frost at a low temperature* (much below 0° C.)."* [5] To what extent the absorptions and the mooted temperature refer to the light cirrus above the caps is not clear. Also a band due to silica has been detected by Coblentz in the light reflected from the red areas of Mars,[10] suggesting that these may be composed largely of acid rocks or products of their decay. No trace of iron oxides has been found in the reflection curves of the light-coloured areas of Mars.

Even more serious than the overlapping of absorptions is the narrowness of our "optical window" which extends from about 3,000 Å. to 8,000 Å. only. Outside these limits the upper layers of our air impose an almost total black-out, and it so happens that the absorption lines of many permanent gases lie precisely there, so that we shall never be able to detect nitrogen (our most abundant atmospheric gas), hydrogen, argon, or helium on other worlds unless and until we can observe them or secure their spectrograms from outside the atmosphere of the Earth.[4] A few years ago this would still have seemed but a very remote possibility. To-day, however, the progress of rocketry has already presented us with air-free spectrograms of the Sun showing multitudes of new absorption lines, and similar spectrograms of the Moon and planets will follow in due course.

The Moon

Solar eclipses, occultations of stars and planets, and spectroscopic examination have all failed to establish the existence of an atmosphere round the Moon; and it has long been a common practice to refer to her as an airless body. Yet a slight obscuration of planetary disks has occasionally been observed at the lunar limb, and systematic digests of the observations of occultation of stars by the Moon would point at the intervention above her surface of a tenuous layer of gas equivalent to between 1/750 and 1/2,000 of the atmosphere of the Earth. The corresponding barometric pressures on the lunar surface would be between 1 mm. and about ½ mm. of mercury.[14] Light mists are at times seen inside some lunar craters, mainly but not only at sunrise, and the veteran American observer of the Moon, W. H. Pickering, even maintained to have witnessed a snow-storm on Pico. Greenish patches of changeable outline have tentatively been attributed to the spread and decay of vegetation in the brief cycle of the lunar day.[4] This evidence, however,

* The italics are his.

has been received by astronomical opinion with great reserve, and only recently has there been a slight change in this attitude.

Last year the Russian astronomer, Y. N. Lipski, claimed to have detected by polarimetric analysis the presence on the Moon of an atmosphere about 0·0001 of the density of our air. His claim has since, it is true, been refuted by the French astrophysicist, B. Lyot, using a still more sensitive test. The matter, however, cannot be regarded as closed. There are indeed other reasons to suspect the existence on the Moon of a thin atmospheric cover. One of these is the absence or great rarity of meteoric impacts upon the lunar surface, many of which would be visible from the Earth. Oddly enough, a lunar atmosphere of the assumed tenuity would provide a better meteoric shield than does the dense atmosphere of the Earth. Owing to the "flatness" of the Moon's gravitational field, the former would extend to great heights with but a slight decrease in density, and meteors become incandescent in our atmosphere at altitudes where the air is no denser than it is expected to be on the Moon.[2] Also the radar echoes received from the Moon would seem to be somewhat fainter than anticipated, which may be explained by the intervention of ionized gas somewhere over her surface.

There are no definite clues to the composition of that atmosphere, but carbon dioxide, ozone, carbonyl sulphide (COS) and sulphur dioxide (SO_2) seem the most likely gases.[5] Water vapour may exist in small amounts, as in view of the low thermal conductivity of lunar rocks deposits of ice (possibly also dry ice) are sometimes suspected in the crevices, pits and gullies where the light of the Sun never penetrates.

A lunar atmosphere of this nature does not necessarily substantiate the observations referred to above, but it would make considerable difference to the projected lunar base, if and when these plans are brought to fruition.

Mercury and Venus

Mercury displays neither absorptions nor unmistakable twilight effects, though the smallness of the disk and the glare of the sky in proximity to the Sun may make the detection of the latter somewhat difficult, while it must be remembered that the dense atmosphere of Venus had for years eluded the spectroscope. The evidence of occultations is likewise negative.

Yet Antoniadi and Schiaparelli, both reliable observers placed in excellent atmospheric conditions, have reported frequent veiling of surface detail, since confirmed by de Vaucouleurs (more frequent than on Mars), by light mists with a diffusion coefficient 0·2, about half that of the Martian clouds.* It also appears not unlikely that the mass and density of the planet are considerably higher than originally thought, the latter (6·2) exceeding that of the Earth and the surface gravity (0·4 g.) that of Mars.[14] This would make a substantial atmosphere intrinsically the more probable. The radiometric data are likewise hard to reconcile with absence of an atmospheric cover. There is no jump of temperature at the terminator, as on the Moon, and the observed minimum temperature of the dark side, which is currently assumed

* E. M. Antoniadi, *La Planète Mercure*, Gauthiers-Villars, Paris, 1934.

to be permanently averted from the Sun, is only −70° C.,[7] much higher than the corresponding lunar figure, although the night on the Moon lasts only about 14 terrestrial days. In fact, last year, a Pic du Midi observer, A. Dollfuss, reported the discovery by polarimetric analysis of a Mercurian atmosphere corresponding to a ground-level pressure of about 1 mm. Hg. An atmosphere of such extreme tenuity would hardly be capable of supporting the condensations or dust particles which could form the observed clouds, so that this may prove to be a gross under-estimate.

The composition of the atmosphere of Mercury might be expected to be broadly similar to that of the Moon. Antoniadi has suggested argon and carbon dioxide as the main components of Mercury's atmospheric mixture.

As already noted, the copious atmosphere of Venus is apparent almost at the first glance. Yet its total depth and mass are not so easy to estimate. From the ring of light observed at transits its refracting layer has been calculated at about 1¼ km. The extension of the cusps at the crescent phase requires a depth of the scattering atmosphere above the cloud banks which form the visible surface of Venus equal to 8 km.; but from the occultations of stars, F. Baldet has obtained 100 km. as the minimum thickness of the upper layers.[3,7] It will be realized that all these estimates fall considerably short of what is known as the exosphere of our air.

The depth of the convective zone beneath the clouds is inaccessible to direct measurement. Yet there are certain recurrent deformations of the terminator near the apparent north pole (the "Ogee" line), which may indicate a cloudless belt seen at an angle. On one occasion a deep dent was observed near the south cusp, and during the 1874 transit the disk of the planet was notched on one side.[14] Interpreted as rifts in the clouds, these observations would indicate a troposphere not less than 30 km. in depth, which seems not unreasonable in view of the probably higher temperature of the Venusian air.

The spectroscope confirms the impression that the atmosphere of Venus exceeds that of the Earth. Adams and Dunham have discovered intense absorptions in the low infra-red which they have identified as due to carbon dioxide. The equivalent atmosphere* corresponding to these absorptions would be about 3 km. thick,[12] and there may be other gases as well. The total equivalent atmosphere of the Earth is only 9 km. (5½ miles)[4] and at least three-quarters of this atmosphere is concentrated in the troposphere; whence it follows that the equivalent atmosphere of Venus cannot be less than 12 km. and is probably a good deal more.

Neither oxygen nor water vapour have been found in the spectrum of Venus, and the Mount Wilson astronomers Nicholson and St. John have put the maximum oxygen content of the visible part of its atmosphere at 0·001 and that of water vapour at 0·1 of the total terrestrial amount.[5] The latter figure need cause no surprise, for the amount of water vapour in our own stratosphere is no higher. The absence of oxygen is more intriguing. Oxygen may, of course, exist below the clouds, but why should it stay there?

There may be a reason for that. Carbon dioxide is a powerful absorber of obscure heat radiated by the surface of the planet. It would thus become

* A fictitious atmosphere of uniform density and under a uniform pressure of 760 mm. Hg.

heated and tend to rise to high altitudes. True, this has not been observed in our atmosphere, but its carbon dioxide content is negligible (0·03 per cent.) and mainly derived from the processes of combustion, vulcanism and respiration on the Earth's surface. On the other hand, ozone, which behaves similarly in relation to the ultra-violet radiations, does ascend to the stratosphere. Further, if we interpret the periodically seen "ashen light" on the dark side of Venus as due to auroral phenomena,[3] these would have to be on a far grander scale than anything known on Earth, and might indicate the existence of a powerful magnetic field round the planet, which would be consonant with its greater proximity to the Sun.

Now gases differ in their magnetic susceptibility. It so happens that the most noticeably paramagnetic gas is molecular oxygen (susceptibility $\kappa = +1434{\cdot}0 \times 10^{-10}$), while carbon dioxide is markedly diamagnetic ($\kappa = -8{\cdot}3 \times 10^{-10}$), a property which increases with pressure.[7] It has, therefore, been suggested by this writer that in the suspected strong magnetic field of Venus, oxygen would have a tendency to descend and carbon dioxide to ascend. The forces would be too small to affect the distribution of gases in the convection zone, but when combined with the thermal effect referred to above might be sufficient to filter out most of the atmospheric carbon dioxide into the stratosphere, where it would create a cushion of hot air, causing a permanent inversion of temperatures and also shielding the planet against loss of lighter gases of the troposphere.

In passing, I may refer to Rupert Wildt's now apparently abandoned suggestion that water vapour ascending in an atmosphere of carbon dioxide would in presence of ultra-violet rays give rise to the reaction:

$$H_2O + CO_2 + h\nu = C_2HO + O_2.^{5}$$

Thus, he contended, the clouds of Venus might consist of formaldehyde floccules, and explained the absence of absorptions due to formaldehyde by its polymerization.[14]

It is often held that Venus is a dessicated globe, devoid of oxygen, from whose unoxidized surface fierce winds raise clouds of white sand, which are all we see. Quite apart from the fact that a hypothesis of this kind seems uncalled for by the observational data, it is improbable on other grounds. A dust-laden atmosphere would appear red in transmitted light; but the dark elusive spots on the surface of Venus, generally thought to be rifts among the clouds, show most distinctly in ultra-violet photographs and are invisible on the red and infra-red ones.[12] Thus the gas beneath the clouds is blue and noticeably free from dust. Also, according to Lyot, the polarization curve of Venus resembles that of light reflected from small droplets.[3]

Mars

So much study has been devoted to Mars that it would require a paper to itself.

From comparison of the planet's radius in the infra-red and ultra-violet photographs secured by W. H. Wright, the depth of the Martian atmosphere where it reflects ultra-violet light sufficiently to affect photographic emulsion

is about 100 km.[13] The twilight arc is 8° wide, whence the scattering layer of the atmosphere works out at about 1/100 of the planet's radius, or some 35 km., which is half the height found by the same procedure on the Earth. Yet, since the twilight arc can in the latter case be followed much farther, the real figures must be more nearly alike. The equivalent atmosphere of Mars has been estimated variously between 1/10 and 1/2 of the Earth's, a discrepancy too large to command much confidence in the methods employed.[7,12]

On the whole the atmosphere of Mars is remarkably clear, but clouds and haze appear in it from time to time, occasionally extending over a large part of the visible disk. These are of three types. The lowest are the so-called "red" (Antoniadi) or "yellow" clouds, whose average height is 3 to 5 km. above the surface.[10] These have often been interpreted as due to dust or volcanic ash, but both these hypotheses encounter considerable difficulties. According to G. de Vaucouleurs, the "yellow" clouds cut down polarization, thus showing that they are absolutely different in composition from the underlying surface, which is inconsistent with their explanation as a dust-bowl phenomenon.[10] Also the velocity of Martian winds is rather low, seldom exceeding 7 km./hr., which is difficult to fit in with this assumption. Antoniadi observed a "yellow" cloud near the limb, where it appeared completely separated from the ground, which is likewise against the hypothesis.[1] Clouds of this type are the most extensive and persistent of the three varieties. They were veiling almost the whole visible disk of Mars from December, 1924, until February, 1925.[1] A volcanic eruption might have produced this effect, but terrestrial vulcanism is associated with large water basins, and the obvious scarcity of water on the surface of Mars constitutes a damaging evidence against widespread volcanic phenomena, although with the low Martian gravity the surface formations may be porous and considerable reservoirs of water may exist underground. In fact, what appeared to be volcanic eruptions has been observed on Mars on several occasions. On the whole, however, it seems more likely that these clouds are in the nature of our fog and owe their creamy or reddish colouring simply to their lower position in the Martian atmosphere, which strongly scatters light of short wavelengths. This is the explanation favoured by Wright and Trumpler.

The white or whitish clouds, similar in appearance to the terrestrial, which often occur in the interesting form of swarms of roundish objects, several tens of kilometres in diameter each, are mainly confined to the "red" areas of Mars. Their height above the surface, according to Cooke and Antoniadi, may exceed 20 km.,[1,9] and they can sometimes be seen as bright prominences at the planet's limb. These clouds are less enduring than the "yellow" type and comparatively rare. Their diffusion factor is rarely above 0·4 as against the terrestrial figure of 0·7, and they probably are of the light cirrus type. White haze has also been observed veiling the edge of the polar caps in spring.

"Blue" clouds, prominent in ultra-violet and violet photographs, but invisible in red light and only faintly noticeable by the naked eye, are more frequent and extensive than the white ones. Antoniadi puts their altitudes at 100 to 150 km.,[1] but de Vaucouleurs' ceiling is only 30 km.,[10] a discrepancy in measurement which is difficult to account for.

It may here be added that, although the Martian atmosphere is considerably less dense than ours, the density gradient is much lower owing to the "flatness" of the gravitational field of "Mars," so that the air rises to greater heights.

It would seem that the high scattering power of the Martian atmosphere is partly due to minute ice crystals, such as have been observed on fine days on the high mountains of the Earth.[5] These crystals would form the so-called "violet layer," which thickens at nightfall into a haze that is held responsible for the observed brightness of the limb, but disperses at sunrise, giving rise to the "glow of vaporization" seen at the eastern terminator. It is possible that the low temperatures recorded on the accessible part of the night hemisphere of Mars (the lowest reading is −85° C.) refer to the "violet layer." This, indeed, is the view favoured by Coblentz and de Vaucouleurs.[10] However, white patches interpreted as hoar-frost have often been observed at sunrise at many points, even close to the Martian equator, so that the night temperature may drop there, at least on higher ground, below the Martian freezing-point of water. This is uncertain, as no reliable estimate of ground-level barometric pressure is available (the equivalent atmosphere assumed above places this between 1/25 and 1/5 of an atmosphere), but will be somewhat lower than on the Earth.[7,10]

On the whole, the climate of Mars does not seem to be greatly different from the extreme continental type encountered on the Earth and may resemble that of Tibet, though variations of temperature between night and day will probably be greater than there.[10]

Our information about the composition of the Martian air is very scanty. In 1947, Kuiper detected carbon dioxide in the spectrum of Mars in an amount about twice the terrestrial. It also shows traces of water vapour and oxygen, but the bulk of atmospheric gases remains unaccounted for. de Vaucouleurs is of the opinion that this is made up of nitrogen, and the present writer suspects on certain grounds that argon may exist on Mars in an appreciable quantity.

The green areas of Mars are most satisfactorily explained as vegetation. The characteristic absorption bands of chlorophyll do not, however, appear in their spectrum; water, too, does not show much. Moreover, unlike our higher plants, the Martian vegetation strongly absorbs red and infra-red light and shows a reflection curve comparable to that of the terrestrial lichens and certain dry mosses. This is in good agreement with the general character of the Martian surface, though it does not follow that the Martian plant forms are actually lichens or mosses. They may be totally unlike them. Scarcity of oxygen, even if confirmed, constitutes no bar to the existence of animals, as chemical reactions whereby oxygen can be obtained from carbon dioxide present no biological difficulty.[5]

The Giant Planets

In the giant planets we have worlds of a species very different from the homely terrestrial kind. The rather forbidding composition of their atmospheres has already been alluded to. In addition to methane and ammonia, Jupiter appears to show some traces of absorption by water vapour,

but no other gases have been found there, although the boiling-point of carbon dioxide (−78° C.) is much higher than that of ammonia (−33° C.) so that it ought to be able to maintain itself in the observable parts of the atmospheres of Jupiter and Saturn, if perhaps not those of Uranus and Neptune.

All accessible surface detail is of a clearly atmospheric nature.

Jupiter, even when viewed through a small telescope, is a brave sight. Apart from the wide bright "zones"—whitish, pinkish, yellowish or greenish in colouring, divided by the darker brownish and reddish "belts," there are spots of green and blue, as well as brilliantly-white oval patches. At first this play of colour was regarded as a purely optical illusion due to the chromatism of the lenses employed. Yet detailed photometric investigation and monochromatic photographs have confirmed the objective reality of most of the observed colorations.[11]

The majority of these features is subject to rapid changes, which often progress before one's very eyes, bearing witness to atmospheric cataclysms beside which our typhoons are light breezes. The velocity of Jovian winds attains 500 km./hour. Owing to his rapid rotation, Jupiter displays phenomena similar to our trade winds, which causes periods of rotation obtained from the observation of spots in different zenographic latitudes to depart considerably from the average of 9 hours 55 minutes.[6] Some of the cloud formations, which are mainly comparable to our stratus, rarely cirrus or cumulus,[3] show distinct atmospheric currents of a permanent character. There also exist surface details of a different type, such as the Great Red Spot, first observed by Cassini in 1665[14] and very prominent in 1878, when it appeared to be of a brick-red colour, but now pale, which endure for centuries. This is not exactly the way of our clouds, but, as we shall soon see, very peculiar conditions obtain in the Jovian atmosphere.

According to the calculations of Edwin Holmes, the high surface gravity of Jupiter (which is about 2·6 g., though the figure is uncertain by something like 10 per cent., as it has been derived from the assumption of uniform distribution of mass inside the Jovian globe) will double the density of his atmosphere with each 2½ km. of depth. Thus, 63 km. below the level where the barometric pressure of one atmosphere is attained, which will happen fairly soon, the Jovian air will become as dense as platinum! The behaviour of gases in such circumstances is not easy to envisage. But solid and liquid bodies would be able to float in them "with the greatest of ease," the height at which they stopped soaring depending on their specific gravity. This would readily explain the Great Red Spot and other semi-permanent features.

Rupert Wildt has suggested that some of the colourings observed on Jupiter may be due to staining of the clouds by brightly-coloured compounds of sodium and ammonia produced by volcanic action. The evidence of infra-red photography would indicate that the "belts" do not lie much lower in his atmosphere than the bright "zones," as is often assumed in explaining their reddish tint by atmospheric absorption.[13] This agrees well with the views advanced by Holmes, who concludes that "the beauty of Jupiter is only skin-deep."[6] (On the other hand, if the gas is strongly compressed, the colouring of the belts may yet be due to atmospheric absorption.)

Yet difficulties arise. The mean density of Jupiter is 1·34 that of water, so that on ordinary reckoning he would have to be hollow inside. The oblateness of the planet requires that the density of the outer layers of the Jovian spheroid should not exceed 1/25 of that of the core.[3]

Holmes has overlooked the powerful centrifugal force at the equator of Jupiter, which in combination with the equatorial bulge will reduce the superficial gravity in these regions by about 1/7 of its mean value. This increases the possible depth of the atmosphere to 23 per cent. of the planet's radius of 71,000 km. Even so, the situation remains baffling,[6] unless very high internal temperatures are assumed.

The "arctic" models of the great planets proposed by Harold Jeffreys and Rupert Wildt,[12] which have lately been in vogue, are likewise not very convincing. These feature a rocky and metallic core surrounded by a carapace of ice thousands of kilometres thick, above which rises a relatively shallow atmosphere of methane, ammonia, hydrogen and helium. Very low temperatures are postulated. Yet ammonia liquefies at −33° C. under the pressure of one atmosphere and much more readily under the enormous pressures which must prevail on Jupiter, so that large amounts of this gas in his atmosphere are hard to reconcile with this hypothesis. Further, Kuiper calculates that a convection zone of only 100 km., which is very little for Jupiter, would require a difference of 190° C. between its top and bottom boundaries.[5] Now the lowest temperature reading on Jupiter is −150° C., and the convection zone, as Kuiper admits, cannot be much less than 500 km., which would make the temperature at its lower boundary about +800° C., with the inescapable conclusion that the interior condition of Jupiter and *mutatis mutandis* of the other giants is semi-stellar. In these circumstances, G. P. Kuiper's final remark about Jupiter's convection zone that "it could not greatly exceed 500 km. because of the high resulting pressures and densities at the base, which would be inconsistent with the planetary model developed by Wildt"[5] makes curious reading. If the temperature at the bottom of this zone goes into thousands of degrees the matter there may yet be of a sufficiently low density to give an over-all mean density of the outer shell that will satisfy the requirements of the planet's oblateness.

Pluto

Pluto is a small body comparable to Mercury in size, though he may be very much denser than the terrestrial planets and represent an unfamiliar planetary species. The issue is *sub judice*. So far no trace of an atmosphere has been discovered on Pluto, but if his mass is 0·9 of the Earth's, the surface gravity will be very high and the atmosphere shallow in proportion, with powerful condensations shielding the surface of the planet from our gaze.

The day may not be far off when we shall make personal acquaintance of the atmospheres of other planets, and I would venture a surmise that these will look very different at close quarters from what we now imagine.

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A NOTE ON THE USE OF DIMENSIONLESS PARAMETERS IN ASTRONAUTICS

By S. W. Greenwood, B.Sc. (Eng.)

The use of dimensionless parameters in studies in gas dynamics and in the development of the gas turbine engine has proved of great value, and it is the purpose of this note to draw attention to the application of this method of manipulating variables to studies in astronautics.

Briefly, the aim is to retain generality by considering the relationships between ratios of variables rather than between single variables. The familiar basic equation in rocketry

$$R_e = e^{\frac{V_e}{V_j}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

is an example of the relationship between two dimensionless variables, R_e and V_e/V_j, and may be represented by a unique curve.

The particular case of escape at constant acceleration from a single gravitational field is treated by Clarke[1] and yields the following approximate equation

$$R_n = e^{\frac{V_e}{V_j}\frac{n+1}{n}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

The reference quoted contains curves for the problem of escape from a particular body, the Earth, so that V_j could be chosen as a parameter, V_e having a definite value. The generality of equation (2) may be retained, however, by using the dimensionless parameter V_e/V_j.

Shepherd and Cleaver[2] derive an equation for the propellant ratio in an atomic rocket motor, which may be written

$$\frac{m_p}{m_f} = \frac{2\alpha\eta}{(V_i/C)^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Since three dimensionless groupings may be plotted on a two-dimensional chart, the three parameters chosen are m_p/m_f, $\alpha\eta$ and V_j/C (C being an absolute constant, V_j may here be considered as if it were a dimensionless parameter, if desired).

Shepherd and Cleaver[3] develop a general equation for the rocket motor, which may be written

$$\frac{V_j^2}{\theta} = \eta \times K^2 \times \frac{F^2}{M} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (4)$$

where K has the value 0·129, for V_j in km./sec.

It is suggested that V_j^2/θ is a more suitable performance parameter than the more familiar V_j. V_j^2/θ is, in effect, the ratio of the effective exhaust kinetic energy to the random kinetic energy of the gases in the combustion chamber, and so takes some account of temperature effects.

Examples of the method of handling variables outlined above may be found in past *Journals* of the Society, but it is thought that this note may serve to focus attention on the value of this type of approach.

Jamison and Mordell[4] refer to the value of the parameter η. Experimental results, when plotted on charts prepared from relations 3 and 4, would render the efficiency of the operation apparent.

Dimensionless parameters retain the generality inherent in any particular problem in dynamics and so permit the universal and continued use of curves plotted with such parameters as variables. The dimensionless nature of such plots also permits a rapid visual assessment of the relative merits of different solutions.

List of Symbols

R_e	Effective mass ratio.
V_e	Total velocity requirement.
V_j	Effective exhaust velocity.
R_n	Mass ratio for constant acceleration ng.
m_p	Total mass rate of discharge in atomic rocket motor.
m_f	Rate of expenditure of nuclear fuel.
α	Fraction of reacting nuclear fuel mass converted into energy.
η	Over-all thermal efficiency of rocket motor.
C	Constant = velocity of light (3×10^5 km./sec.).
θ	Gas temperature in rocket motor chamber at start of expansion (° K.).
F	A factor defined in ref. 3.
M	Mean molecular weight of gases in rocket motor expansion process.

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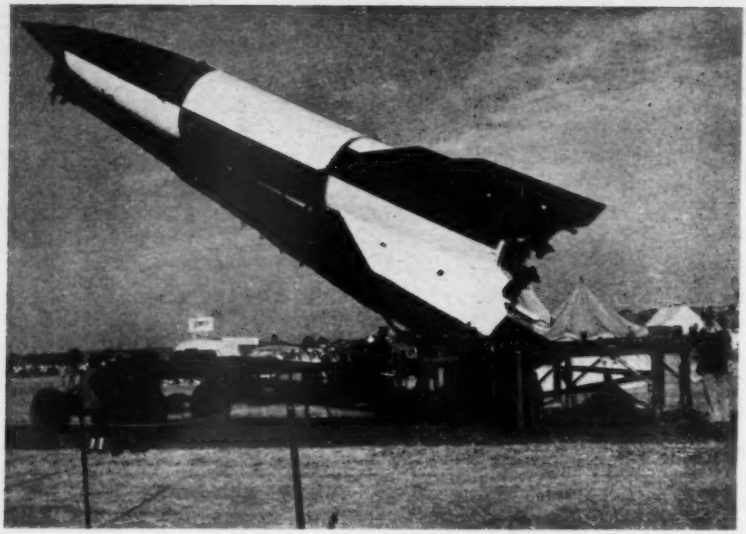

V2 at Hendon Air Display, July 19–21, 1951.

DR. WERNHER VON BRAUN
CHARACTERISTICS OF THE EARTH'S ATMOSPHERE
THE V 2 ROCKET
CIVILIAN V2
1948
DR. EUGEN SÄNGER
Since the War, V 2's have been used extensively for research into the upper atmosphere. Here is a rocket modified for this work.

Photo: *"Daily Graphic"*

A wall panel at Hendon Air Display, July 19–21, 1951.

NOTES AND NEWS

International Congress, Souvenir Postcards

As souvenirs of the Second International Congress on Astronautics, 1951, the Council has made available a set of six souvenir postcards depicting the following scenes:—

(*a*) The German A4 Rocket (*photo British Interplanetary Society*).
(*b*) View of the Earth at 60 miles altitude (*photo U.S. Navy*).
(*c*) Building a Space Station (*drawing by R. A. Smith from "The Exploration of Space," Temple Press, Ltd.*, 12*s.* 6*d.*).
(*d*) The Lunar Landscape (*photo Lick Observatory*).
(*e*) The Rocket in a Lunar Crater (*scene from "Destination Moon"*).
(*f*) Imaginary view of Saturn from its Nearest Satellite (*from a painting by Chesley Bonestell in "The Conquest of Space," Sidgwick & Jackson, Ltd.*, 21*s.*).

The postcards are available at 2s. per set, post free, from the B.I.S. Secretary at 157, Friary Road, London, S.E.15. Those prepared for the Second International Congress will be issued first in strict rotation, and remaining orders will be completed by the issue of similar cards not specifically printed for the Congress.

Astronautics at Hendon

On July 19–21, at Hendon Aerodrome, the *Daily Express* organized, in conjunction with the Royal Aero Club, an exhibition entitled "50 Years of Flying." The whole display was of great aeronautical interest—many pioneer aircraft being present and some of them, such as the 1909 Blériot monoplane, actually taking to the air.

About a month before the event the B.I.S. was approached and requested to organize an astronautics feature for the exhibition. This occupied the end of a large marquee and consisted of a number of wall panels showing the development of the astronautical idea, pioneers of rocketry, current work and conceptions of future space ships. A model of a man-carrying rocket (*J.B.I.S.*, **7**, 3, May, 1948) was displayed, as well as a large cut-away model of a spaceship loaned by the Brighton and Hove Society of Model Engineers. A V2, borrowed from the Science Museum, together with its conveyer and travelling crane, formed a prominent landmark outside the tent.

B.I.S. officials were in attendance during the whole of the display to deal with queries, and there is no doubt that the exhibit attracted a great deal of attention. One visitor was the Lord Mayor of London, who volunteered to go on the *second* spaceship to the Moon! Most of the reactions were favourable, but there were some sceptics—such as the gentleman who looked at the model spaceship and muttered to himself: "What a waste!" There was also a small boy who gave one look round, snorted "Dan Dare!"* and walked out in disgust.

These, however, were the exceptions, and those responsible for the exhibit feel very gratified by its reception and the interest it aroused. Its effect has already been reflected in current applications for membership, and it must

* *For the benefit of our overseas members, a character in a well-known juvenile cartoon set in the future.*

have brought the idea of space-travel home to a great many people who had not taken it seriously before.

New Astronautical Societies

Since we published a comprehensive list of the world's astronautical societies in the 1950 B.I.S. *Annual Report*, news of several additional organizations has reached us.

In the first place, mention should be made of one society which was inadvertently omitted from the above list; although it was represented (by its President) at the 1950 Paris Congress, we were without information on it at the time our summary was compiled. We refer, of course, to the *Asociación Española de Astronáutica* (A.E.A.) of Madrid, of which Senor Tomás Mur (a well-known Spanish civil engineer) is President.

The other additions to the growing international astronautical movement are of more recent formation. We learn from Ing. Åke Hjertstrand (also a delegate to the 1950 Paris Congress) that a *Swedish Interplanetary Society* was formed on October 16, 1950. After one meeting of its temporary Council (of which he is a member), further activities were postponed until after this summer, although a short radio talk and a lecture to one of the branches of the Swedish Association of Engineers and Architects have been given.

From Norway comes news of the formation on August 21, 1951, of the *Norsk Interplanetarisk Selskap*, under the Chairmanship of Erik R. Bergaust, with headquarters at Mogens Thorsens gate 9, Oslo. The Vice-President is Thorstein Thelle, Secretary Gunnar Oxaal, and other Members of the Board are K. Bergersen and Commander H. Bloch-Hoell. Moving from the more rigorous Scandinavian climate to the sunny Mediterranean, we find the *Associazione Italiana Razzi* starting up in Rome, with temporary offices under the roof of the Associazione Italiana di Aerotecnica (A.I.D.A.) at Piazza S. Bernardo 101. Its first President is the famous aviation pioneer and aeronautical scientist, General Professor G. A. Crocco, who conducted some interesting experiments with liquid-propellant rocket motors for the Italian Government in the nineteen-thirties. Prof. Ing. Antonio Eula of Rome University is the Secretary of the A.I.R., and the Provisional Council also includes Prof. Dr. G. Abetti, Dr. Ing. G. P. Casiraghi and Prof. Dr. Ing. E. Pistolesi. With such distinguished academic support right from its inception, we can surely expect the new Italian Rocket Association to undertake some valuable technical work.

A final, and most welcome, item of news concerning our sister societies abroad has reached us from Dr. Günter Loeser, the author of the article pleading for an International Astronautical Research Institute which was published in the July *Journal*. He tells us that agreement in principle has been achieved at last for the amalgamation of all the Western Zone German societies, which had their previous headquarters at Stuttgart, Frankfurt and Stade (near Hamburg). The new large society will simply be called the *Gesellschaft fur Weltraumforschung* (G.f.W.,—without geographical labels such as N.W., S.W., etc.), and will be based in Frankfurt.

At about the time this appears in print the Second International Astronautical Congress will be taking place in London. Following its conclusion, we shall no doubt have still more news to report about the growth of the astronautical movement in various countries, but even the preceding paragraphs indicate its healthy state.

From the World's Press

The 99th Convention of the Electrochemical Society, in Washington, D.C., were told by Clark E. Thorp of the Armour Research Foundation, Chicago, that the way was now open to the production of ozone (O_3) on a tonnage basis. He was reported in the *Washington Post*, *Business Week*, and elsewhere, as saying that recent research has shown how to stabilize this form of tri-atomic oxygen, by "removing various thermal, mechanical, electrical and chemical sensitizing influences" during its preparation. The work involves very delicate techniques, however, with remote manipulation by mechanical devices from behind shielding, in a manner reminiscent of the chemistry of radio-active substances. Basically, the method of manufacture consists of passing electrical discharges through normal oxygen, and the result is a dark blue fluid, valuable as a high-performance oxidant for rocket motors. Denser than normal liquid oxygen, and of course possessing some energy content of its own, ozone will also, according to Mr. Thorp, be safer to handle than liquid fluorine—its main future competitor as a super-oxidant, e.g., for spaceships.

In view of all the current "lesser-of-several-evils" argument which goes on about the relative claims of liquid oxygen, nitric acid and hydrogen peroxide, it is refreshing (at least) to encounter some discussion of ozone *v.* fluorine! Things to come . . . or the pleasures still in store for rocket engineers.

* * * *

Several references to rocketry and space flight were made at the New York meeting of the American Chemical Society last May, and were widely reported in the popular and technical Press.

In particular, Mr. A. J. Nerad, of General Electric, thought interplanetary rockets were a "marginal" possibility even with chemical propellants. Nuclear heating of a hydrogen jet was admittedly a future possibility, as also was the discovery of some method of "fixing" mon-atomic hydrogen, but Mr. Nerad thought present chemical fuels, such as hydrogen or the hydroborons, burned with ozone, would also be adequate, and would be available sooner and more cheaply. He conceded the many detail problems still awaiting solution, but said these were "of the type which have been solved many times before" in the history of other branches of technology. Step construction would, of course, be used.

Mr. P. F. Winternitz, of Reaction Motors, Inc., supported Mr. Nerad, and thought that after a little more propellant development and the "solution of a few minor technical problems," we should be ready to conquer space. Dr. Bonner, speaking later in the discussion, said that their simplicity and high density might even give solid chemical propellants an advantage for powering spaceships. (This is strongly reminiscent of the pre-war B.I.S.!)

Air Chief Marshal Sir Alec Coryton (Chief Executive, Guided Weapons, at the Ministry of Supply) expressed satisfaction with progress on the Anglo-Australian Rocket Range, when he returned to London after his recent visit there. He also re-iterated his view of the extreme national importance of work on guided missiles at the present time, and was quoted by *The Times* on March 31 as regarding our progress as satisfactory "in relation to the total effort devoted" to it so far.

* * * *

Scientists of the Canadian National Research Council, talking to the Press about their new hypersonic wind-tunnel just completed at Ottawa, said that aerodynamic research conducted in it (at Mach Numbers up to 7) would contribute essential data towards the solution of the first problem presented by space flight—namely, the high-speed penetration of the atmosphere. Space ships, of course, will need to attain such speeds while still within the atmosphere, though only by the time that they have reached heights where the air density is so low that aerodynamic resistance and heating effects are not large. Knowledge of such phenomena will nevertheless be very necessary, and especially so in connection with the possibility of using wings as a landing mechanism for rockets returning to Earth.

* * * *

Rather similar opinions to the above Canadian ones were also expressed, on a similar occasion a month or so previously (during May), by John Stack, Assistant Research Chief of the American National Advisory Committee for Aeronautics (N.A.C.A.). He told reporters that researchers at the N.A.C.A. establishments at Langley Field and nearby Wallops Island—a singularly aptly-named base for launching test missiles!—were already working on the basic problems of spaceships and "Earth satellite vehicles." However, the work so far was "purely exploratory," and not directed towards any specific interplanetary aim. Rather, it was designed to solve the aerodynamic problems of future aircraft which might fly at 3,000 m.p.h. and 160,000 feet.

* * * *

No doubt Mr. Stack had in mind such aircraft as the Bell X.2, which was credited by "experts outside the American Air Force," in Press reports last March, to be likely to attain 2,500 m.p.h. at 200,000 feet when fully developed. Mention has also been made of an equally (or even more) advanced Douglas project—the X.3. We wonder, somewhat wistfully, when we shall hear of some hope of British participation in this competition to go still higher and faster. After all, we *did* hold the world's speed record not so long ago—and still hold the "official" aeroplane altitude record of 59,445 feet. (Oddly enough, the most ancient aerial vehicle of all—the balloon—has taken men to a height nearly 10,000 feet greater than this!)

In the meantime, recent U.S. Navy statements have revealed that their Douglas "Skyrocket" research aircraft has flown at speeds of "about 1,500 m.p.h." and heights of "60,000 to 70,000 feet," although no actual official records were claimed. Security considerations, and perhaps also difficulty in complying with regulations for setting up new records (since these were

drafted for more conventional aircraft), were no doubt responsible for the latter fact. The "Skyrocket," for its latest exploits, adopted the technique of air-launching from a B.29, previously developed for the U.S.A.F. Bell X.1. Also, its auxiliary turbojet engine, originally fitted to facilitate take-off, climb and cruising, was removed and replaced by tanks for extra rocket propellants.

The latter change draws attention to a characteristic of such supersonic rocket aircraft. Unlike types with conventional propulsive systems, once they attain (as it were) their own element, at extreme heights, they have no steady "top speed" condition, where engine thrust just balances air resistance. They normally cannot carry enough propellants to accelerate up to such a condition; best thought of as piloted rocket projectiles with wings, they are still rapidly increasing their speed when they run out of fuel!

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The *News-Chronicle* for May 16 carried a long article (by Geoffrey Murray) on the B.I.S. This was the sort of sympathetic popular publicity, intelligent and accurate, which the astronautical movement welcomes: it is a happy sign of the times that such treatment of the theme is becoming increasingly frequent. The article concluded: "(the B.I.S.) seek to fulfil the prophecy of H. G. Wells that a time would come when life will stand upon earth, as upon a footstool, and stretch out its realm amongst the stars."

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An editorial in the *New York Times* on May 13, devoted some attention to Gordon Thompson's B.I.S. paper on "The Lunar Base." Its author thought that "Poets will shudder at what may seem to them a degradation of the Moon," but rejected such a view himself. He went on to say: "Mr. Thompson's proposals are tinged with romance, yet they have a sound theoretical engineering core. . . . The dreams of to-day are the realities of to-morrow."

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The *New York Times* on June 10, also printed a short but factual account of the recent paper by Engel, Bödewadt and Hanisch on the establishment of space stations and their use for orbital refuelling of spaceships. (See B.I.S. *Journal*, Abstract No. 47, March, 1951.) The intrusion of such a technical item on astronautics into the columns of this important American newspaper is, we think, significant. Of course, we must remember that the *New York Times* slogan has long been "All the news that's fit to print"—but it is good to find we agree on the standard!

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British and foreign papers alike gave some prominence recently to the proposals for spaceship development of the three German engineers, Rudolf Nebel (of the old V.f.R.), Albert Pullenberg and Karl Poggensee. They thought initial experiments should be conducted with man-carrying single-stage chemical rockets; then, in up to 20 years' time, the construction of multi-step, atomic-powered, true space ships would become feasible.

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The Reuter agency, in a report on the Military College of Science at Shrivenham, Wiltshire, says that, among the teaching staff there: "One

scientist is conducting private experiments on Moon rockets." This somewhat highly-coloured account no doubt refers to the mathematical researches of our own D. F. Lawden; while we believe these have sometimes involved the use of the College's differential analyser, they have not yet led to the actual construction of a back-yard (or barrack-square) spaceship!

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Early in July, many papers, both here and abroad, made reference to statements made in the documentary film "Forward a Century," made by Basic Films, Ltd., for the Petroleum Films Bureau, and first shown in the Telecinema of the South Bank Festival Exhibition. This excellent little film, running for about 30 minutes, contrasts the Exhibitions of 1851 and 1951, depicts all the social and scientific advances made in the century which separates them (and which were undreamed of by the smug Victorian age), and ends with short statements by five scientists and engineers on what *we* can expect if we look "Forward a Century." Most papers (and especially *Reynolds News* for July 8) seized on the opinion of Professor Massey, of University College, London; that, by 2051, atomic energy will be driving "not only machinery, but ships and aircraft and even interplanetary rockets," and also the quietly-confident concluding prediction of our own Val Cleaver, that: "Within the next 50 years we shall probably have flown to the Moon, and by 2051, voyages to Mars and Venus may be commonplace."

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Drs. Kirchoff and Bleksley, of the South African Astronomical Society, recently told the papers that the Union would probably be the site of the base from which the first lunar spaceship would be launched, because: "Africa has the necessary space and latitude, and has an altitude high enough to eliminate the most difficult mile of the trip through the densest atmosphere." These are indeed cogent reasons, but the newspaper reports we have seen gave fewer details in support of the surprisingly precise suggestion, from an official of the Pretoria Weather Bureau, that July, 1964, was a probable date for the actual take-off! This has an air of the end-of-the-world announcements periodically made by the "Repent and be Saved" school. . . .

Dr. Bleksley, a lecturer in applied mathematics at the University of the Witwatersrand, said that "South African youth comes from adventurous stock, and the trip to the Moon is the one great adventure of exploration left to modern youth." Interviewed by the *Johannesburg Sunday Express*, Mr. J. Durrand ("a Rand educationist") agreed with this, and said: "Boys in our schools are wildly enthusiastic about interplanetary travel, rockets and spaceships." However (see previous item), the reporter concerned had the same conflicting experience as his *News-Chronicle* colleague, because he found only one 17-year-old who wanted to go. This probably proves the profound truth that "it takes all sorts to make a world," and that the adventurous and unadventurous exist side-by-side in all places and all age groups.

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The famous aviation pioneer and industrialist, Sir Frederick Handley-Page, recently predicted interplanetary travel within about 50 years, saying that the

possibility was no more absurd than certain prophecies made about aircraft 40 years ago, which had now been realized or surpassed.

Less inclined to accept our views in such a matter-of-fact way is, apparently, Mr. F. D. Grimwade, a Fellow of the Royal Astronomical Society, who was quoted by *The Observer* as having said: "The more we realize how unearthly things are in outer space, the more, I think, we shall be content to stay here." Curiously enough, we have often heard exactly the same argument used in reverse, as a reason for leaving!

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The Times of London on May 31, reported Dr. D. F. Martyn's Masson Memorial Lecture to the Australian and New Zealand Association for the Advancement of Science, at Brisbane. He predicted the establishment of "Earth satellite vehicle" rockets in orbits 25,000 miles from the Earth within about 10 years, and described their uses. Dr. Martyn, Chief Scientist of the Australian Radio Research Board, a Fellow of the Royal Society (and of the B.I.S.!), has been much in the news recently in connection with his advocacy "down under" of such orbital rocket projects. As one of the world's leading radio experts, he is, of course, specially well-qualified to appreciate their value as short-wave relay stations, etc.

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The *Halifax Courier and Guardian*, in a "how-times-have-changed" mood, reported wonderingly on June 30 that the midsummer fair in the old home town this year had a roundabout which was "a rocket to the Moon with jet exhaust tubes."

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Last May the *News-Chronicle* took 10-year-old Michael Kelly to the South Bank Exhibition, and duly reported his indignant query: "Why is there no rocket?" (We agree with him—though the excellent model of the solar system there is some compensation, and one of the most popular attractions, too.) Then, on July 20, the same paper found "six boys between 7 and 12," at the *Daily Express* "Fifty Years of Flying" display at Hendon, who were much less space-minded. (We shall have to think up a happier description of the astronautical enthusiast than this. . . .) All six, questioned about their willingness to go on the lunar trip predicted on the B.I.S. stand "before the end of the century," said they thought it would be much too risky.

We think young Kelly is probably more typical of the youth of this modern age; anyhow, we know at least one 16-year-old who would be keen to volunteer —and if he was not, we should in any case lose no opportunity to push him aboard just before take-off. There is the recent instance, too, of Mr. C. G. Grey's question, "Why Waste Money Going to the Moon?" in the *Lancashire Daily Post*. Following his rash query, this doyen of aviation journalists suffered a terrific tearing-off of strips in the paper's correspondence columns, first from "18-year-old Interplanetary Flight Enthusiast," and then from "14-year-old Interplanetary Flight Enthusiast." The latter of these two

concluded his letter, above his mouthful of a *nom de plume*, with magnificent disdain: "A lunar flight is merely an obvious and natural step in man's progress, which scientists will take because we are not, fortunately, all like Mr. Grey."

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Sir Harry Garner, Chief Scientist of the British Ministry of Supply, told Australian journalists that: "If interplanetary flight experiments are ever carried out, the Woomera rocket range in Central Australia will be the ideal place for them." So South Africa (see above) has a competitor within the British Commonwealth! (One, moreover, which has already been favoured by selection in the novel *Prelude to Space* by the B.I.S. Chairman . . . but then, the pre-war B.I.S. made South America their choice, launching from a high-altitude lake in the Andes called "Titterhaha," or something equally improbable. . . .)

Sir Harry, when he made the observation in question, had just returned to Melbourne from his visit to Woomera with Sir Alec Coryton (Chief Executive of the British Guided Weapons programme). They said that Woomera would play a vital part in Commonwealth defence plans. Statements in the Australian Press at about the same time said that guided missiles would probably soon be manufactured in Australia, and that expenditure on the range would have reached £20,000,000 by this summer. The population of Woomera is now over 3,500, including over 200 complete families who had made their home there, now that the growing desert township has some of the amenities of civilization.

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Dr. Urner Liddel is Head of the Nuclear Physics Section of the U.S. Office of Naval Research. He recently expressed his conviction that all reports of "flying saucers," which did not originate in pure hallucination or hoaxes, were the result of people seeing the large balloons used by his organization and others for cosmic ray research. This explanation has gained almost universal acceptance, even in the States. Now Dr. Liddel, in *Science News Letter* for April 14, has disposed also of the current crop of "flying saucer" books. The conclusion to his long review of Gerald Heard's *Is Another World Watching Us?* deserves quotation: "The perpetration of such a book spreading solely fear psychology at this time, especially by such a reputable publisher, is, in my humble opinion, completely inept." This, of course, after a scathing consideration of the author's "scientific" arguments. We should like to have seen a few more such outspoken reviews, by reputable authorities, of the regrettable number of pseudo-scientific books which have appeared recently from publishers of whom one would have expected better.

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American papers reported that the same Russian spy ring which was seeking atomic information, and of which several members have recently received severe sentences, was also interested in the Earth-Satellite-Vehicle Programme. Most of the accounts, however, stress that no practical work on this is yet in progress,

e.g., Louis Cassels in the Canadian *Vancouver Sun* wrote on March 17: "The U.S. Army, Navy, and Air Force have been conducting research on satellite vehicles for the past five years or more. But the work has been limited to theoretical studies and component designs—the kind of essential preliminary work that will be invaluable when and if it becomes practical to build such vehicles." He concludes by quoting a statement by a scientist of Johns Hopkins University: "Spaceships are no longer fantastic—but it will be a damned long time before they are practical."

True—but time marches on, if we may coin a phrase.

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Two different reactions to the argument that the Interplanetary Age may unite mankind came recently from opposite ends, as it were, of the Commonwealth. Reporting a lecture by a Mr. Gladstone Murray, who had said that space-flight would induce "a new and wholesome sense of proportion," the Toronto *Saturday Night* was gloomy. The *Calcutta Statesman*, apparently editorializing just for the fun of it, was more cheerful.

Wrote the Canadians ". . . the process of taking possession of America after it had been discovered was one of almost continuous conflict . . . the prospect of a similar conflict over the colonization of Mars leaves us definitely cold. And the present measure of success attending the organization and putting to work of the United Nations does not encourage us to expect an easy time when we have to tackle the organization of the United Planets."

By way of compensation, the Indians, a few days previously, had gone into print with the view that "Against a Martian attack, the human race, forgetting domestic quarrels, would be (or at least ought to be) at last united."

Personally, we prefer Mr. Murray's more civilized comment to either of these preoccupations with war and strife; moreover, we believe that in the long run his point will prove the most significant. We enjoyed, however, some of the earlier comments on possible extra-terrestrial life-forms in the "Calcutta Statesman"; for example, "Lunar people, by the best known traditions, should be beautiful but malevolent fairies, who delight in robbing men of the little sanity they possess. Saturnines, according to Indian lore, exude all that is evil, nor are they in any case cheerful company."

ABSTRACTS

Edited by J. HUMPHRIES

Abbreviations of titles of journals were given in the May, 1950, issue of the *Journal*, and addenda have appeared in subsequent issues. The following is a further addendum to the list.

Atti Accad. Naz. Lincei (R.C.Cl. Sci. Fis. Mat. Nat.).	Atti dell' Accademia Nazionale di Lincei. Rendiconti della Classe di Scienze Fiziche, Matematiche e Naturali.
Bull. U.S.S.R. Acad. Sci. Sect. Tech. Phys.	Bulletin of the U.S.S.R. Academy of Sciences. Section of Technical Physics.
Dokl. Akad. Nauk, S.S.S.R.	Doklady Academie Nauk, S.S.S.R.
Elektroteh. Vestn.	Elektrotehniski Vestnik.
Forsvarets ForsknInst. Årb.	Forsvarets Forskninginstitut Årbok.

Izv. Akad. Nauk, S.S.S.R.	Izvestiya Akademii Nauk, S.S.S.R.
Izv. Akad. Nauk, S.S.S.R., Ser. Fiz.	Izvestiya Akademii Nauk, S.S.S.R., Seriya Fizicheskaya.
Photogr. Engng.	Photographic Engineering.
Proc. Inst. Radio Engrs.	Proceedings of the Institute of Radio Engineers.
Rev. Sci. Instrum.	Review of Scientific Instruments.
Tekn. Tidskr.	Teknisk Tidskrift.

Many of the articles noted are available on loan to members resident in the British Isles. Requests should be addressed to J. Humphries, 97, Churchill Avenue, Southcourt, Aylesbury, Bucks.

AIRCRAFT

(124) **The use of auxiliary rockets in high-speed aircraft.** Z. PLASKOWSKI. *Aircraft Engng.*, **23**, 72-75 (*March*, 1951). [Trans. from *Flugwehr u. Technik*, (6) (1950).] See abs. No. 91.

(125) **Application of rocket power to aircraft.** H. R. MOLES. *Aero. Engng. Rev.*, **10**, 24-30 (*April*, 1951).

The characteristics of rocket power plants are first presented. A brief history of the application of rocket power to missiles is given. The more common propellants for aircraft application and methods of storing low-temperature boiling propellants are described. The major advantages of a rocket power plant in an aircraft are listed, and a typical arrangement of a pump-fed rocket power plant is described. Finally, the question of whether an effective military rocket-powered interceptor can be built to-day is examined.

ASTRONAUTICS

(126) **Proof of the possibility of space-flight.** H. H. KÖLLE. *G.f.W. Report*, No. 7, 35 pp. (*30th Nov.*, 1950). (*In German.*)

General introduction to rocketry dealing first in detail with design of single and multi-stage rockets. The space station and supply rockets, using normal chemical propellants are next dealt with, together with the cost of such a project. A Moon rocket is proposed, assuming the existence of a space station and using liquid oxygen/liquid hydrogen produced on the space station from water. An interplanetary rocket would require atomic propulsion and this together with other problems of space-flight are discussed. (14 *refs.*)

(127) **Trends in astronautics.** K. W. GATLAND. *Sky and Telescope*, (110), 27 (*Dec.*, 1950).

Summary of recent work, particularly that of the B.I.S.

(128) **A suggested design project on an orbit rocket.** L. J. GRANT. *J. Space Flight*, **3**, (1), 1-5 (*Jan.*, 1951).

Proposal for a 2-stage 400-mile orbit rocket. Payload 1,000 lb., all-up weight 126,000 lb.

(129) **Space-rockets and Earth satellites.** *Tekn. Tidskr.*, **81**, 61-64 (*27th Jan.*, 1951). (*In Swedish.*)

(130) **Rockets as extremely rapid transportation.** H. BARTENBACH. *J. Space Flight*, **3**, (2), 1-2 (*Feb.*, 1951).

Earth satellites.

(131) **The station in space.** H. OBERTH. *Rocketscience*, **5**, 2-5 (*March*, 1951).

Translation from "Wege zur Raumschiffahrt."

(132) **Astronautical themes to be worked on.** R. ENGEL. *Weltraumfahrt*, (2), 29-34 (*April*, 1951). (*In German.*)

Discussion of outstanding work that could be carried out by the G.f.W. Includes space station orbital problems, trajectories for supply ships, step release mechanisms, battery charging from Sun's rays, electrical potentials of spaceships, remote control of rockets and theoretical combustion work.

(133) **Navigation of spaceships.** G. SCHRUTKA-RECHTENSTAMM. *Natur u. Technik*, **5**, 108-109 (*April*, 1951). (*In German.*)

ASTRONOMY

(134) **Venus and the Earth's inner core.** K. E. BULLEN. *Mon. Nat. Roy. Astr. Soc.*, **110**, 256-259 (1950).

The application of the compressibility-pressure model to Venus.

(135) **Laws of planetary distances and planetary revolution.** L. E. GUSEVITCH and A. I. LEBEDINSKI. *Dokl. Akad. Nauk, S.S.S.R.*, **74**, 1061 (1950). (*In Russian.*)
Theoretical relations between distances, masses and rotations are deduced.

(136) **On the instability of small planetary cores.** *Mon. Nat. Roy. Astr. Soc.*, **110** (1950). Pt. I, W. H. RAMSEY, 325-338. Pt. II, M. J. LIGHTHILL, 339-342.

(137) **Planetocentric effect of radial retardation.** V. V. RADZIEVSKI. *Dokl. Akad. Nauk, S.S.S.R.*, **74**, 197-200 (1950). (*In Russian.*)
Rate of decrease of orbital radius is calculated for all the planets except Pluto.

(138) **The planets and the white dwarfs.** W. H. RAMSEY. *Mon. Nat. Roy. Astr. Soc.*, **110**, 444-454 (1950).
Russell's relationship between the planets and the white dwarfs is explained on the basis of the atomic theory of solids.

(139) **The origin of planets and their satellites.** O. Y. SCHMIDT. *Izv. Akad. Nauk, S.S.S.R., Ser. Fiz.*, **14**, 29-45 (1950). (*In Russian.*)

(140) **On the origin of the solar system.** G. ARMELLINI. *Atti. Accad. Naz. Lincei (R.C.Cl. Sci. Fis. Mat. Nat.)*, **9**, 135-141 (*Sept.-Oct.*, 1950). (*In Italian.*)

(141) **A surface mechanism analogy between meteors and explosives.** M. A. COOK and R. N. THOMAS. *Astr. J.*, **55**, 167 (*Oct.*, 1950).
The reaction-rate method is applied to the vapourization of meteor material. (Lecture summary.)

(142) **A new determination of the lunar parallax.** J. A. O'KEEFE. *Astr. J.*, **55**, 177 (*Oct.*, 1950).
Photo-electric observations of occultations made in the U.S., together with data from the geodetic triangulation of the U.S. yield a value of lunar distance of 384,410 international km. (Lecture summary.)

(143) **Geological interpretations of the markings on Mars.** C. W. TOMBAUGH. *Astr. J.*, **55**, 184 (*Oct.*, 1950).
Among other interpretations the seasonal colour changes are attributed to vegetation, the "oases" to craters caused by collisions with asteroids, and the "canals" as cracks caused by fracture of the planet's crust under the impact of the colliding asteroids. (Lecture summary.)

(144) **On the origin of the Taurid meteors.** F. L. WHIPPLE and S. EL- D. NAMID. *Astr. J.*, **55**, 185 (*Oct.*, 1950).
An analysis of the orbits and perturbations suggests that the shower originated in two ejections from comet Encke, 4,700 and 1,500 years ago. (Lecture summary.)

(145) **The orbit of the meteor of 3rd April, 1949.** C. C. WYLIE. *Astr. J.*, **55**, 187 (*Oct.*, 1950). (Lecture summary.)

(146) **The structure and chemical composition of Mars.** H. C. UREY. *Phys. Rev.*, **80**, 295 (15*th Oct.*, 1950).

(147) **Diffuse reflection by planetary atmospheres.** H. G. HORAK. *Astrophys. J.*, **112**, 445-463 (*Nov.*, 1950).
An attempt is made to give a quantitative interpretation of photometric observations using Chandrasekhar's laws of diffuse reflection.

(148) **Problem of the dissipation of planetary atmospheres.** I. S. SCHKLOOSKI. *Dokl. Akad. Nauk, S.S.S.R.*, **76**, 193-196 (1951). (*In Russian.*)
A formula is deduced which supersedes the classical formulae of Jeans, Milne, Jones and Spitzer.

(149) **The origin of the Moon.** K. E. BULLEN. *Nature*, **167**, 29 (6*th Jan.*, 1951).
The resonance theory is re-examined in the light of recent theories of the interior of the Earth (Ramsey).

(150) **Deceleration and the ionizing efficiency of radar meteors.** D. W. R. MCKINLEY. *J. Appl. Phys.*, **22**, 202-213 (*Feb.*, 1951).

(151) **On diffusing particles in the atmosphere of Mars.** E. SCHATZMAN. *C.R. Acad. Sci., Paris*, **232**, 692-693 (19*th Feb.*, 1951). (*In French.*)

(152) **Determination of the atmospheric pressure on the planet Mars.** A. DOLLFUS. *C.R. Acad. Sci., Paris*, **232**, 1066-1068 (12*th March*, 1951). (*In French.*)
The pressure at ground level was determined as 83 mb. by four different polarization methods.

ATMOSPHERE

(153) **Meteoric echo study of upper atmosphere winds.** MANNING, VILLARD and PETERSON. *Proc. Inst. Radio Engrs.*, **38**, 877 (*Aug.*, 1950).

(154) **The upper atmosphere—its exploration and exploitation.** W. LEY. *Aero. Engng. Rev.*, **10**, 20-24, 30 (*Feb.*, 1951).

Review of history of upper atmosphere research with brief résumé of present knowledge. Sänger-Bredt antipodal bomber is discussed.

BIOLOGY AND MEDICINE

(155) **All aboard for Jupiter!** *Naval Aviation News*, 11 (*Feb.*, 1951).

Report on space medicine lectures.

(156) **Silicon as a base for life forms.** N. BOWMAN. *J. Space Flight*, **3**, (3), 1-6 (*March*, 1951).

The simplest case is based on an Si—Si chain replacing the normal C—C chain. The second case is a life-form based on an Si—O—Si bonding with an atmosphere of either NH_3 or HF. All of these are considered improbable.

CHEMISTRY

(157) **Catalytic decomposition of highly concentrated hydrazine by Raney nickel.** L. F. AUDRIETH and W. L. JOLLY. *J. Phys. Coll. Chem.*, **55**, 524-531 (*April*, 1951).

Studies of 96 to 99 per cent. hydrazine with a view to its use as a monopropellant.

MISCELLANEOUS

(158) **Rocket propelled illuminating flare.** C. N. HICKMAN. U.S. Pat. No. 2,503,269 (*11th April*, 1950).

(159) **Life and work of Konstantin Eduardovich Tsiolkovskiĭ (1875-1935).** B. N. YUR'EV. *Bull. U.S.S.R. Acad. Sci., Sect. Tech. Phys.* (12), 1865 (*Dec.*, 1950). (*In Russian.*)

(160) **Konstantin Eduardovich Tsiolkovskiĭ, founder of modern rocket dynamics.** A. A. KOSMODEM'YANSKIĬ. *Bull. U.S.S.R. Acad. Sci., Sect. Tech. Phys.* (12), 1872 (*Dec.*, 1950). (*In Russian.*)

(161) **The preservation of archives on the Moon.** W. PROELL. *J. Space Flight*, **3**, (2), 3-6 (*Feb.*, 1951).

(162) **Steel ball holds nitrogen at 5,500 p.s.i.** *Aviation Wk.*, **54**, 28, 31 (*26th March*, 1951).

Construction details of welded stainless steel sphere to hold 200 galls. liquid nitrogen.

PHOTOGRAPHY

(163) **Preliminary report of high altitude photography.** C. T. HOLLIDAY. *Photogr. Engng.*, **1**, 16 (*Jan.*, 1950).

PHYSICS

(164) **Maximum heat transfer to boiling water at high pressures.** E. A. KAZAKOVA. *Izv. Akad. Nauk, S.S.S.R.* (9), 1377-1387 (*Sept.*, 1950). (*In Russian.*) [Extensive abs. in *Engrs. Dig.*, **12**, 81-85 (*March*, 1951).]

The heat transfer from a platinum wire heated by alternating current to boiling water is described. The pressures used range from 1-200 atmos.

(165) **Hydrogen at high temperatures.** I. BREDT. *Z. Naturforsch.*, **6a**, 103-112 (1951). (*In German.*)

The values of specific heat, enthalpy, entropy and degrees of dissociation and ionization are calculated and plotted for hydrogen from $1{,}000^\circ$ to $10{,}000^\circ$ K. and from 10^{-3} to 10^6 atmos. The released mechanical energy after adiabatic expansion is given for various conditions. It is assumed that the hydrogen can be heated and curves are given for equilibrium conditions and for various degrees of freedom frozen in.

(166) **An analog computer for flame gas composition.** W. S. MCEWAN and S. SKOLNIK. *Rev. Sci. Instrum.*, **22**, 125-132 (*March*, 1951).

An analog computer has been developed which simulates electrically the conditions of temperature, pressure and composition of combustion products. These conditions are imposed as resistances in a series of interlocking Wheatstone bridges which, when balanced, produce the required resistances proportional to partial pressures. Mole fractions are

obtained by dividing the partial pressures by the total pressure which also is produced as a proportional resistance by the computer.

PROJECTILES

(167) **Nomogram for performances of step-rockets.** R. ENGEL. *G.f.W. Report No.* 6, 8 pp. (*In German.*)

The problem of very large first stage rockets is dealt with and it is suggested that small rockets in groups could be used instead. A nomogram covering the proposal is included.

(168) **Rocket launching apparatus.** F. C. EASTMAN. U.S. Pat. No. 2,485,715 (*25th Oct.*, 1949).

(169) **Rocket target.** J. B. EDSON. U.S. Pat. No. 2,485,870 (*25th Oct.*, 1949).

(170) **Rocket projectile.** S. GOLDEN. U.S. Pat. No. 2,490,349 (*6th Dec.*, 1949).

(171) **Rocket type weapon.** R. B. STAVER. U.S. Pat. No. 2,490,101 (*6th Dec.*, 1949).

(172) **Rocket projectile.** G. J. KESSENICH. U.S. Pat. No. 2,494,562 (*17th Jan.*, 1950).

(173) **Rocket projectile.** E. F. CHANDLER. U.S. Pat. No. 2,500,117 (*7th March*, 1950).

(174) **Rocket projectile.** C. N. HICKMAN. U.S. Pat. No. 2,503,271 (*11th April*, 1950).

(175) **Projectile.** E. F. CHANDLER. U.S. Pat. No. 2,504,648 (*18th April*, 1950).

(176) **Means for mounting rockets on aircraft.** A. THORRATT. U.S. Pat. No. 2,506,976 (*9th May*, 1950).

(177) **Viking sets new altitude record.** C. ROBERTS. *Martin Star*, **9**, 7-8, 11 (*June*, 1950).

Firing of Viking Four from U.S.S. Norton Sound.

(178) **Step-motor rocket projectile.** C. N. HICKMAN. U.S. Pat. No. 2,510,110 (*6th June*, 1950).

(179) **Rocket research report No. III: Vibration in the Viking No. III rocket.** L. B. CUNNINGHAM, E. E. BISSELL, L. H. A. FEHER and R. W. STROUP. *U.S. Naval Res. Lab., Washington, Rep. No.* 3695, 40 pp. (*10th July*, 1950).

Vibrational frequencies and amplitudes occurring in the war-head and adjacent to the rocket motor were observed during the static firing tests and during flight of the Viking No. 3 rocket. Experimental procedures and results are presented.

(180) **Magazine rocket launcher.** L. MOTLEY. U.S. Pat. No. 2,517,333 (*1st Aug.*, 1950).

(181) **Rocket projectile.** C. F. BJORK. U.S. Pat. No. 2,519,878 (*22nd Aug.*, 1950).

(182) **Directed missile.** M. B. ROBINSON. U.S. Pat. No. 2,520,433 (*29th Aug.*, 1950).

(183) **Means for cooling projected devices.** R. H. GODDARD. U.S. Pat. No. 2,522,114 (*12th Sept.*, 1950).

(184) **Photographic determination of the orientation of a rocket.** L. W. FRASER and R. S. OSTRANDER. *Photogr. Engng.*, **1**, 105-118 (*Oct.*, 1950).

The problems of rocket orientation in general and the particular problems applying to high altitude rockets are defined and discussed. A photographic method of high altitude orientation is developed to fit the need and illustrated by means of models, mathematical formulae and photographs. The construction and use of a perspective grid which may be developed from the photographs made from the rocket is described and a sample grid is given.

(185) **Operations with the high altitude sounding rocket Viking (Rockets 1 through 4).** J. P. LAYTON. *Amer. Rocket Soc. National Convention*, 21 pp. (*30th Nov.*, 1950). [Extensive abstract as "Viking flights prove research worth," *Aviation Wk.*, **54**, 24-26, 28 (*15th Jan.*, 1951).]

The Viking and its associated equipment are described. The flights of Nos. 1-4 are chronicled. Nos. 1-3 were fired at White Sands and No. 4 reached an altitude of 106·4 miles from the deck of U.S.S. Norton Sound. An outline of typical operations with Viking are given and operational aspects commented on.

(186) **First rocket-borne temperature-measuring experiments set.** *C.A.D.O. Techn. Data Dig.*, **15**, 7 (*Dec.*, 1950).
Viking and Aerobee experiments.

(187) **Life story of a Viking rocket.** *Martin Star*, **10**, 13-17, 19 (*Jan.*, 1951).

(188) **Inside the Navy Viking test rocket.** *Aviation Wk.*, **54**, 33 (*22nd Jan.*, 1951).

(189) **Above the Earth's atmosphere.** L. HANSEN. *Ingenioren*, 104-106 (*27th Jan.*, 1951). (*In Danish.*)

(190) **Rockets to-day.** J. R. RANDOLPH. *Ordnance*, **35**, 300-301 (*Jan.-Feb.*, 1951).
Military potentialities of rocket and ram-jet missiles.

(191) **Missiles streak toward future role.** D. A. ANDERTON. *Aviation Wk.*, **54**, 66-68 (*26th Feb.*, 1951).
Classifies types of missile, details work in progress in U.S. and discusses aerodynamic and propulsion problems.

(192) **Anti-aircraft rockets.** H. K. KAISER. *Rocketscience*, **5**, 16-18 (*March*, 1951).

(193) **Missiles for various occasions.** *Flight*, **59**, 428 (*13th April*, 1951).

(194) **Rockets and models.** *Aeroplane*, **90**, 482 (*20th April*, 1951).

RADIO AND ELECTRONICS

(195) **Electrical apparatus for control of the V2 rocket.** D. ZAVADLAV. *Elektroteh. Vestn.* (11-12), 333-338 (1950). (*In Czech.*) Translation from *Elektrotech. Z.* (*E.T.Z.*), **71**, 281-287 (*22nd May*, 1950). (*In German.*) For abs. see *J.B.I.S.*, **9**, 292 (*Nov.*, 1950), abs. No. 20.

(196) **Rocket electronics.** H.-M. CHRISTIANSEN. *Das Elektron*, **5**, 21-28 (*Jan.*, 1951). (*In German.*)
Describes electronic control of V2. At cut-off the angle, velocity, direction and distance have to be correct. Angle and direction are controlled by gyroscopes which can be overridden by a signal from the ground. The velocity was originally decided by a gyroscopic type of integrating accelerometer, but this was replaced later by an electrolytic type. The distance is determined by use of a radio-doppler system.

(197) **Radio telemetry.** M. H. NICHOLS and L. L. RAUCH. *Rev. Sci. Instrum.*, **22**, 1-29 (*Jan.*, 1951).
A review of the theory of telemetry dealing mainly with frequency division multiplexing and time division multiplexing and a comparison of the two methods. Other topics covered are instrumentation and airborne recording. No discussion of techniques is included. (**76** *refs.*)

(198) **Proportional radio control.** G. R. URQUHART. *Aero. Dig.*, **62**, 20-21, 73-74, 91 (*Feb.*, 1951).
The proportional and the "on-off" radio control systems are compared on the bases of reliability, three-dimensional control, and recovery of the missile after landing.

ROCKET MOTORS

(199) **Pressure pick-up.** G. P. SUTTON. U.S. Pat. No. 2,485,515 (*18th Oct.*, 1949).
For use in rocket combustion chambers.

(200) **Fuel and water feeding and steam discharge arrangement for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,487,435 (*8th Nov.*, 1949).
Steam generator.

(201) **Obturator trap for rocket propellants.** C. N. HICKMAN. U.S. Pat. No. 2,487,053 (*8th Nov.*, 1949).

(202) **Fuel controlling apparatus for longitudinally movable combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,496,710 (*7th Feb.*, 1950).
Device to vary fuel flow in response to thrust change.

(203) **Pumping apparatus for very cold liquids.** R. H. GODDARD. U.S. Pat. No. 2,496,711 (*7th Feb.*, 1950).
Membrane type pump.

(204) **Ignition apparatus for combustion chambers using intermingled combustion liquids.** R. H. GODDARD. U.S. Pat. No. 2,498,263 (*21st Feb.*, 1950).

(205) **Means for preventing excessive combustion pressure in rocket motors.** J. O. HIRSCHFELDER. U.S. Pat. No. 2,497,888 (21*st Feb.*, 1950).

(206) **Movably mounted auxiliary vanes on rotating combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,500,537 (14*th March*, 1950).

(207) **Jet motor operable by monopropellant and method of operating it.** M. J. ZUCROW. U.S. Pat. No. 2,500,334 (14*th March*, 1950).

(208) **Application of nuclear energy to rocket problems.** N. SCHOLZ. *Weltraumfahrt* (2), 40-44 (*April*, 1950). (*In German.*)

(209) **Trap for rocket propellants.** C. N. HICKMAN. U.S. Pat. No. 2,503,270 (11*th April*, 1950).

(210) **Jet-adjusting means.** W. B. POPE. U.S. Pat. No. 2,503,684 (11*th April*, 1950).

(211) **Trap for rocket propellants.** C. N. HICKMAN. U.S. Pat. No. 2,502,458 (15*th April*, 1950).

(212) **Liquid fuel jet propulsion system.** L. A. SKINNER. U.S. Pat. No. 2,505,798 (2*nd May*, 1950).
Use of collapsible tank liners.

(213) **Jet motor with cooling system.** M. J. ZUCROW. U.S. Pat. No. 2,508,590 (23*rd May*, 1950).

(214) **Rotatable discharge nozzle for fixed combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,510,570 (6*th June*, 1950).

(215) **Combustion chamber with annular target area.** R. H. GODDARD. U.S. Pat. No. 2,510,571 (6*th June*, 1950).

(216) **Mixing partition for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,510,572 (6*th June*, 1950).

(217) **Side venting rocket.** L. A. SKINNER. U.S. Pat. No. 2,510,147 (6*th June*, 1950).

(218) **Multiple rocket motor.** C. C. LAURITSEN. U.S. Pat. No. 2,515,048 (11*th July*, 1950).

(219) **Rocket motor relief means construction.** C. C. LAURITSEN and O. C. WILSON. U.S. Pat. No. 2,515,049 (11*th July*, 1950).

(220) **Propulsion apparatus actuated by successive charges of detonating materials.** R. H. GODDARD. U.S. Pat. No. 2,515,643 (18*th July*, 1950).

(221) **Feeding means for rotating combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,515,645 (18*th July*, 1950).

(222) **Double jacket means for feeding two liquids to a rotating combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,516,462 (25*th July*, 1950).

(223) **Ring valve construction for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,518,001 (8*th Aug.*, 1950).

(224) **Means for feeding concentric liquid sprays to a rotating combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,518,002 (8*th Aug.*, 1950).

(225) **Ring valve construction for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,518,003 (8*th Aug.*, 1950).

(226) **Fuel feeding and cooling construction for rotating combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,518,881 (15*th Aug.*, 1950).

(227) **Combined igniting and fuel feed control mechanism for a thrust unit.** R. H. GODDARD. U.S. Pat. No. 2,518,882 (15*th Aug.*, 1950).

(228) **Reaction motor with fluid cooling means.** M. J. ZUCROW. U.S. Pat. No. 2,520,751 (29*th Aug.*, 1950).

(229) **Means for cooling powder-burning combustion chambers and nozzles.** R. H. GODDARD. U.S. Pat. No. 2,522,113 (12*th Sept.*, 1950).

(230) **Turbine starting and control apparatus.** R. H. GODDARD. U.S. Pat. No. 2,523,008 (19*th Sept.*, 1950).

(231) **Power take-off for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,523,009 (19*th Sept.*, 1950).
Method of taking off combustion gases for turbine drive.

(232) **Auxiliary power take-off for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,523,010 (*19th Sept.*, 1950).

(233) **Cooling and feeding means for rotating combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,523,011 (*19th Sept.*, 1950).

(234) **Intermittent feed mechanism for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,523,012 (*19th Sept.*, 1950).

(235) **Feeding and cooling wall structure for combustion chambers using liquid combustion elements.** R. H. GODDARD. U.S. Pat. No. 2,523,654 (*26th Sept.*, 1950).

(236) **Rotating combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,523,655 (*26th Sept.*, 1950).

(237) **Combustion apparatus comprising successive combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,523,656 (*26th Sept.*, 1950).

(238) **Rocket research in the twentieth century.** J. W. SIRY. *Sci. Mon.*, **71**, 408-421 (*Dec.*, 1950). [Extensive abs. in *Mech. Engng., N.Y.*, **73**, 322-324 (*April*, 1951).]
A review of the work of Goddard, Oberth, Winkler, V.f.R., Peenemünde, A.R.S., GALCIT Jet Propulsion Laboratory, Reaction Motors Incorporated and the upper atmosphere research now being carried out in the U.S. (20 *refs.*)

(239) **Stability of flow in a rocket motor.** H. I. ANSOFF and M. YACHTER. *J. Appl. Mech.*, **18**, 114-116 (*March*, 1951). Comments on original paper—see *J.B.I.S.*, **10**, 42 (*Jan.*, 1951), abs. No. 33.

(240) **Ballistics program at Ohio State University.** C. J. PEIRCE and W. P. BERGGREN. *J. Amer. Rocket Soc.* (84), 34-38 (*March*, 1951).
Teaching and research programs are described briefly with details of liquid hydrogen/oxygen rocket motor tests.

(241) **Principles of rocket-turbopump design.** C. C. ROSS. *J. Amer. Rocket Soc.* (84), 21-33 (*March*, 1951).
Discusses design of the different components which make up the complete unit, with particular emphasis on pump parameters. The suction specific speed of the pumps is shown to be the controlling parameter in determining a minimum fixed-weight design for both auxiliary and prime rocket power plants, whereas such factors as pump efficiency, turbine efficiency and propellant performance must be individually treated, depending on the specific application.

ROCKET PROPELLANTS

(242) **Liquid propellants for rockets.** B. OTTAR. *Forsvarets ForsknInst. Årb.*, **2**, 413-441 (1948-49). (*In Norwegian.*)
Introduction to liquid-propellant rocket motors and details of propellants used by Germany.

(243) **Strip propellant for rocket projectiles.** A. AFRICANO. U.S. Pat. No. 2,488,154 (*15th Nov.*, 1949).

(244) **An analysis of properties of some rocket fuels.** G. NEBBIA. *Ann. facoltà econ. com. Univ. Bari.*, **9**, 13-17 (1949). (*In Italian.*)

(245) **General method for computation of equilibrium composition and temperature of chemical reactions.** V. N. HUFF and V. E. MORRELL. *N.A.C.A. Tech. Note No.* 2113, 47 pp. (*June*, 1950).
A rapidly convergent successive approximation process is described that simultaneously determines both composition and temperature resulting from a chemical reaction. This method is suitable for use with any set of reactants over the complete range of mixture ratios as long as the products of reaction are ideal gases. An approximate treatment of limited amounts of liquids and solids is also included. This method is particularly suited to problems having a large number of products of reaction and to problems that require determination of such properties as specific heat or velocity of sound of a dissociating mixture.

(246) **Hazards involved in use of rocket propellants.** M. C. DUNNAM. *C.A.D.O. Techn. Data Dig.*, **15**, 18-20 (*Nov.*, 1950).
Safety precautions in handling red and white fuming nitric acids, xylidene, aniline and furfurol.

REVIEWS

The Origin of the Earth

(By Professor W. M. Smart. 239 pp., illus. Cambridge University Press, 1951. Price 12s. 6d.)

At first sight it might seem as though a book devoted to the origin of the Earth would be of little immediate interest to members of the B.I.S. Such, however, is not the case, as Professor Smart has incorporated a great deal of valuable information upon the solar system, atomic structure and allied topics. The chapter on radio-activity, for instance, is extremely clear, and probably the best outline of the subject that the reviewer has read.

The book is divided into three sections, "Whence?" "When?" and "How?" The first part is devoted mainly to a very clear and concise description of the Earth, Moon and planets; the second to a discussion of the Earth's probable age, and the third to the various theories put forward to account for the creation of the Sun's family of planets.

There are a few unimportant misprints. On p. 71 it is stated that the markings on Mercury are faint and seldom seen, which is hardly correct in view of the accurate maps produced by Antoniadi and others; the discovery of a tenuous atmospheric mantle around the planet had not been made when the book was written. Nor is it quite correct to say that Venus is featureless in the telescope (p. 72), though the markings on the "Evening Star" are certainly vague and ill-defined.

The binding, print and illustrations are extremely good; the whole book is written in the author's usual clear style, and can be thoroughly recommended as a most interesting and useful volume. P. A. M.

Physique de la Planète Mars

(By Gérard de Vaucouleurs. 424 pp. Editions Albin Michel, Paris, 1951. Price 825 francs.)

This is a most important book which should be read by everyone interested in astronautics, particularly as it is many years since any major work dealing with Mars has appeared—though several semi-popular accounts have been published, the most recent being by M. de Vaucouleurs himself.

The present work is aptly summed up by its sub-title, "Introduction to Areophysics." No space is wasted upon vague speculations about the canals and possible Martians, but modern physical methods of research into the condition of our neighbour world are described in detail. The book is divided into five main sections, "Atmosphere," "Climates," "Polar Caps and Water," "The Martian Surface" and "Internal Constitution," and each of these subjects is dealt with in the author's usual clear, concise style. There is also a lengthy and well-chosen bibliography.

The type is good—though, as is frequently the case with Continental publications, the binding leaves something to be desired—there are no discernable errors in the text, and the few misprints that occur are very minor. P. A. M.

Stalin Means War

(By Col. G. A. Tokaev. 214 pp., pub. George Weidenfeld & Nicholson, Ltd. (London). 12s. 6d.)

Prelude to Space

(By Arthur C. Clarke. 160 pp., pub. World Editions, Inc. (New York), as "Galaxy Science Fiction Novel No. 3." 25 cents.)

It would probably be difficult to find more dissimilar books than the pair listed above, yet they have two things in common which justify this joint treatment if only on grounds of economy of explanation. Each belongs to a class not normally reviewed in this Journal, and each, we think, is likely to be of particular interest to our readers.

"Stalin Means War" is essentially a political work, written by a refugee Russian Communist who was a highly-placed technical officer in the Red Air Force. He describes his life in the U.S.S.R. and gives his reasons for believing that the Soviets are planning a world war against the Western democratic nations. However, while B.I.S. members can be no less interested in these matters than other potential victims of such a conspiracy, it is not our usual practice to discuss them in these non-political pages. Our reason for making an exception in the present case is that the author cites current Russian interest in the Sänger project in support of his arguments. In fact, quite a large section of his book is taken up by this point, and very fascinating reading it makes, too.

The "Sänger project" has now been fairly extensively described in the periodical literature of aeronautics—a good recent account being Willy Ley's "The Upper Atmosphere: its Exploration and Exploitation," in the February, 1951, "Aeronautical Engineering Review" of the Institute of Aeronautical Sciences (Vol. 10, No. 2). Briefly, it was a proposal for a huge 100-ton supersonic bomber, piloted and rocket-propelled, to have a range making possible non-stop round-the-world flights after launch from a rocket-driven carriage running on a long ground track. An undulatory flight path was intended to be followed, rather reminiscent of the path of a stone skimmed across the surface of a pond. In fact, the procedure followed would have been very similar indeed, with the craft spending much of its time well beyond the atmospheric levels considered for normal flight, and "skimming" the boundary of those denser strata. The originator of this German war-time scheme was Dr. Eugen Sänger (now an Honorary Fellow of this Society), who wrote a lengthy report on it in collaboration with Frau Dr. Irene Bredt.

Tokaev was one of the senior engineers sent on behalf of the U.S.S.R. in 1945 to investigate the results of German wartime aeronautical developments. Like similar investigators from the Western countries, he soon encountered copies of the Sänger-Bredt report (which seems to have received a rather wide confidential distribution within Germany), and sent them back to Moscow with his comments. These latter, as repeated in the book, appear to have been very sound; he appreciated, for example, that Dr. Sänger regarded his project as a theoretical study of an ultimate possibility (given a certain

programme of prior research which was carefully enumerated in the report), and not as a design on which construction could immediately be started.

The reception of the Sänger report in Moscow, however, seems to have startled even Tokaev by its enthusiasm and desire for early and energetic action. He was recalled to explain further details, first to boards of officials, and finally to a meeting of the Politbureau in the Kremlin, presided over by no less than Stalin himself. As a result, Tokaev was sent back to Berlin with orders to locate Sänger and bring him to Russia to achieve the realisation of his ambitious scheme. In these commissions, of course, he failed completely, since Dr. Sänger is now working near Paris for the French Government. (He is also President of the Provisional Committee set up to consider an International Astronautical Federation in preparation for the 1951 London Congress.)

Tokaev's book describes all this incident in considerable and very interesting detail, marred only by occasional incongruous translations of technical phrases. It is maintained that Stalin's desire to push forward on such military rocket projects as Sänger's affords further convincing proof of his aggressive intent. Without necessarily disputing the author's central thesis (which may well be only too true), one might nevertheless feel that some of Stalin's words (as quoted in the book) are capable of a rather less sinister interpretation: "Tokaev, we wish you to exploit Sänger's ideas in every way . . . . You realise its vital importance? . . . . You see, we live in an insane epoch." Tokaev describes the last as "a curious remark," but few of us, even on this side of the Iron Curtain, would disagree with it. One wonders whether the Russians are not as frightened of us as we are of them.

Being a work of fiction, and moreover concerned with a future, saner, more civilised society, "Prelude to Space" is much less terrifying than "Stalin Means War." Because it is fiction, it again falls into a class of literature which we do not normally review, though perhaps we might be forgiven for making an exception in its favour on the grounds that it was written by the Chairman of the B.I.S. However, an even better excuse for doing so is afforded by the fact that it is an extremely good documentary account, cast in the form of fiction, of how space-flight *may*—and we hope *will*—finally be achieved. That is, it describes the work, leading up to the take-off of the first Lunar expedition, of an organisation called "Interplanetary," based in London but wholly international in character. "Interplanetary" is charged with the task of astronautical development for purely peaceful and cultural objectives, instead of leaving it to be the fortuitous end-product of military research on such things as the Sänger project.

The book is dedicated to the present reviewer, "despite his proof that nuclear ramjets are totally impracticable." This seems to call for a re-affirmation of the opinion that approval of Clarke's political approach cannot wholly be extended to the technical means by which he suggests that it might be carried out! His spaceship *Alpha* is launched from a winged first step *Beta*, which uses a nuclear-powered ramjet engine to furnish a substantial contribution towards its attainment of orbital velocity in the extreme upper reaches of the atmosphere.

Following an earlier (much earlier: "Prelude" was written in 1947) technical

argument, the text carefully avoids stating just how "substantial" this velocity contribution might be; however, the case against there being any really worthwhile value in this superficially very attractive idea of a ramjet first step, may briefly be outlined as follows:—

Consider rocket and ramjet engines, each having the same throughput mass flow (M) and energy input (E). At the maximum throughway (A) of the reaction chamber of each, the gas flow velocity (v), before expansion in the propulsive nozzle, should also be comparable—with a reasonably low value ensuring sufficient time for energy transfer to take place in this working section, without excessive friction losses. Then, for either engine:—

$$M = \rho A v, \text{ by continuity}$$

or

$$M = \frac{Pm}{G\theta} \cdot Av, \text{ from the Gas Laws}$$

where P, θ and m are the pressure, temperature and molecular weight, of the gaseous working fluid in the chamber, and G is the Universal Gas Constant. It is also true that:—

$$E \simeq c_p M \theta$$

where c_p is the specific heat of the gas and assuming that the initial temperature of the working fluid is about the same for each engine, also neglecting the temperature rise due to ram compression for the ramjet. (Since the latter will be very large, this assumption would not be justified in any practical case, but it is adequate for our present purpose, since proper allowance for its intake temperature rise places the ramjet in an even more unfavourable light, by further reducing the working fluid density in the chamber.) Hence:—

$$A = \frac{GE}{v} \cdot \frac{I}{mc_p} \cdot \frac{I}{P}$$

$$\therefore A \propto \frac{I}{P} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

since G and E are the same for each engine, while v will be approximately so, as also will be the product mc_p (either for the working fluid of air for the ramjet, or any other gas for the rocket).

Now, if:—

T = thrust
U = flight velocity
and V = exhaust velocity

with subscripts r and j to denote rocket and ramjet respectively, then:—

$$T_r = MV_r$$

$$T_j = M\ (V_j - U)$$

For the ideal condition of expanding over an infinite pressure ratio in each case (*i.e.*, down to zero external pressure):—

$$E = \tfrac{1}{2} M (V_j^2 - U^2) \times \tfrac{1}{2} MV_i^2$$

(Actually, the rocket will be better off in this respect, since for the practical

case of a given finite exit pressure, its expansion ratio will be larger due to its higher chamber pressure—but neglect this.)

$$\frac{T_r}{T_j} = \frac{V_r}{(V_j - U)} = \frac{V_r}{(V_r^2 + U^2)^{\frac{1}{2}} - U} \quad \ldots\ldots(2)$$

Comparing thrusts per unit frontal area, from (1) and (2):—

$$\frac{T_r/A_r}{T_j/A_j} = \frac{V_r}{(V_r^2 + U^2)^{\frac{1}{2}} - U} \cdot \frac{P_r}{P_j}$$

Now consider the case of operation at a flight speed (U) of 10,000 m.p.h. and an altitude of 100 miles—conditions which might be regarded as a substantial contribution towards the orbital state. At 100 miles height, the external air density (ρ_0) is only 2×10^{-9} lb./ft.^{3}, and the pressure 7×10^{-7} lb./ins.^{2} Even on the highly optimistic assumption of perfect dynamic compression, the ramjet could achieve a ram pressure rise of only $\frac{1}{2}\rho_0 U^2$, so that $P_j > 0{\cdot}00005$ lb./ins.^{2} By comparison, even present rocket motors have chamber pressures $P_r < 300$ lb./ins^2 and probably future types would be much higher. For present chemical rockets $V_r \simeq 5{,}000$ m.p.h., while for future nuclear rockets it may be as high as 20,000 m.p.h., taking a rough mean value of 10,000 m.p.h., we have:—

$$\frac{T_r/A_r}{T_j/A_j} = \frac{10{,}000}{(10{,}000^2 + 10{,}000^2)^{\frac{1}{2}} - 10{,}000} \times \frac{300}{0{\cdot}00005}$$

$$= 2{\cdot}4 \times 6{,}000{,}000$$

$$= 14{,}400{,}000.$$

Thus, the ramjet would be a decidedly bulky device, since it would have a frontal area several million times greater (for these particular operating conditions) than a rocket giving the same thrust. In practice also, it would prove impossible to secure the necessary heat transfer to such a tenuous working fluid, in the same way as the absolute air pressure in its chamber sets an upper limit to the altitude at which combustion can be supported in a ramjet burning chemical fuels.

It therefore seems very unlikely indeed that ramjet propulsion can make any useful contribution towards astronautical missions, though perhaps one should always refrain from using the word "impossible," in view of the dismal fate of so many other negative prophecies throughout the history of science and technology. The arguments involved really throw some light on the proper relation between rocket and ramjet engines of any sort, the latter being (by comparison) essentially low-altitude devices. In spite of the phrasing of Clarke's dedication, the case against the ramjet for very high-altitude work is not limited to any hypothetical nuclear-powered version—though it is true that such a type would be even worse off than orthodox combustion ramjets burning chemical fuels. For the latter, almost the whole frontal area of the device is available as gas throughway, whereas for a ramjet containing a nuclear reactor, presumably only a very small fraction would be.

A. V. C.

CORRESPONDENCE

Misplaced Credit

SIR,

If he has been reported aright, Mr. A. C. Clarke is doubly in error when he states (B.I.S. *Journal*, **10**, 157, July, 1951) that Mr. C. Littlewood Askham, of the Pools, paid for the first issue of this publication. At the time in question (*circa* 1934), C. H. L. Askham was not connected with the firm of Littlewoods (though he had earlier assisted in starting the enterprise, and had, in fact, given his name to it), nor did he pay the cost of the first issue of the *Journal*. As I have previously recounted in these pages ("Matters of No Moment," **9**, 49, March, 1950), that was another's privilege, and it was in fact myself who pocketed the bill for the first printing, the work of George Reed & Company, of Liverpool.

When it became evident that the Society was without sufficient funds to finance a second issue, Askham agreed to approach his one-time associate, John Moores, with whom he remained on friendly terms, and who now numbered a printing establishment among his many and varied concerns. As a result, the second and third issues of the *Journal* were produced without cost to the Society, under the imprint of J. & C. Moores Publicity Ltd. Due reference to this timely assistance was subsequently made in my *Rockets Through Space*, viz.—

> "Eventually, at the instigation of C. H. L. Askham, a firm of publishers interested themselves in our plight, generously offering to print two issues of the *Journal* without charge."

The name of the Society's benefactor was purposely not mentioned in this account, because of an expressed desire for strict anonymity. Millionaire John Moores was more than willing to answer the call of his friend, but he wisely shrank from open association with a group of half-wits who were planning to lay hold of the Moon!

Throughout the years I have felt bound to respect this wish for secrecy, at any rate outside the confines of the B.I.S. Council Chamber. And if I publicly break my silence at long last, it is merely to ensure that the right cat is let out of the right bag—with profound apologies to all concerned.

Heswall, Cheshire. P. E. CLEATOR.

Mr. Clarke writes:

"I am very glad that my slip has resulted in this credit being given where it is due, and will take the opportunity of reminding any millionaires associated with the Society in its early days that we will always be glad to welcome them back into the fold!"

RECENT AND FORTHCOMING MEETINGS

June 25, 1951 (Monday). "Rocket Propulsion and Interplanetary Flight," by A. V. Cleaver, to the Astronomical and Scientific Societies of Eton College, Windsor, Berks.

July 9, 1951 (Monday). "Interplanetary Travel and Rocket Flight," by G. V. E. Thompson, to the 3rd Goodmayes (St. Andrew's) Group Senior Scout Section, at St. Andrew's Presbyterian Church, Goodmayes Road, Goodmayes, Essex, at 7.30 p.m.

July 27, 1951 (Saturday). "Rocket Development," by L. J. Carter, to 1st New Cross Scouts, at The Hut, Coulgate Street, Brockley Cross, S.E.4, at 8 p.m.

September 8, 1951 (Saturday). "Concluding Session of the Second International Congress on Astronautics," to the Society, at Caxton Hall, S.W.1, at 3 p.m.

September 15, 1951 (Saturday). "The Work of the Pacific Rocket Society," by E. V. Sawyer of the P.R.S., to the N.W. Branch of the Society, at Adult Education Institute, 49, Lower Mosley Street, Manchester, 2, at 7.15 p.m.

September 22, 1951 (Saturday). "Modern Sounding Rockets," by E. Burgess, to the N.W. Branch of the Society, at Adult Education Institute, Manchester, at 7.15 p.m.

September 25, 1951 (Tuesday). "Rockets and Space Travel," by J. Humphries, to Handley Page Engineering Society, Cricklewood, N.W.2, at 6 p.m.

October 6, 1951 (Saturday). "Summary of Technical Papers delivered at the Second International Congress on Astronautics," to the Society, at Caxton Hall, S.W.1, at 6 p.m.

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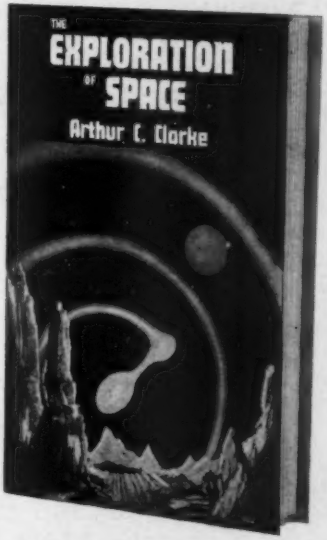

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CARLETON COLLEGE, NORTHFIELD, MINNESOTA, U.S.A.

PRINTED BY W. HEFFER & SONS LTD., CAMBRIDGE, ENGLAND

THE IMPORTANCE OF SATELLITE VEHICLES IN INTERPLANETARY FLIGHT

(A Paper presented at the Second International Congress on Astronautics, held in London from 3rd to 8th September, 1951)

by

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The giant airliners which fly the transcontinental and transoceanic lanes are the result of several decades of persistent effort to improve aerodynamic configurations, mass ratios and performance of power plants. But any antiquated small airplane can fly around the globe if we subdivide her flight into a number of short hops and allow her to refill after each landing.

The trouble with rocket flights into the planetary world is that interplanetary filling stations are few and far between. Therefore, a Mars-or Venus-bound rocket ship, taking off from the Earth's surface would have to carry all propellants required, down to those for the final power maneuvers of the return voyage. As a result, it would have to be an immensely large and heavy ship with a power plant of truly astronomical proportions.

If we want to avoid the knotty problem of developing such a super space ship, we should first build those filling stations. It is one of the main tasks of the satellite vehicle to establish such a filling station for interplanetary flights.

There is a widely held belief, even among space travel enthusiasts, that interplanetary voyages with chemically-propelled rocket ships involve such tremendous quantities of propellants that the technical feasibility of such trips must be questioned, even for very limited payloads. It has therefore become a habit to hint at mysterious "atomic propellants" and "nuclear rocket drives" which could do the trick better. I have no desire nor intention of decrying the eventual application of this source of power to navigation of interstellar space. When referring to technological advances, the word "impossible" must be used, if at all, with utmost caution. We should not forget, however, that all speculation on nuclear power sources for rockets is still founded on rather shaky ground. Thus, we render our cause a service of dubious value by referring to such vague potentialities. I, for one, am not yet convinced that within the next quarter of a century we will have a nuclear rocket drive that could economically compete with chemical power plants.

Factors such as required thrust ratings or radioactive contamination of launching sites render the problem of developing a nuclear rocket ship, suitable for take-offs from Earth, much more involved than the development of an

orbit-to-orbit space ship for exclusive use in empty space. Therefore, the first atomic-driven rocket will probably start from the orbit rather than from the Earth's surface. The main burden of any voyage into the planetary world, viz., the prefatory supply flights into an orbit around the Earth, would even then have to be borne by chemically-propelled ships.

Rocket designers generally agree that at least threes stages are required for a satellite rocket ship with chemical propellants. If such a ship is to serve for the preparation of an interplanetary flight originating in the satellite orbit, it must be capable of carrying aloft a liberal amount of payload.

The ship's last stage must be able to safely return to the Earth's surface after unloading its payload in the orbit. Such a return is possible if we equip the upper stage with wings. By a short power maneuver in the orbit, the circular velocity would be reduced by an amount adequate to induce the upper stage into a "landing ellipse" whose perigee is located in the tenuous upper layers of the atmosphere. In a long-stretched glide, first flown with a negative, later with a positive angle-of-attack, it would gradually be decelerated by air drag, until it descended to subsonic speed and subsequently landed on a tricycle landing gear in airplane fashion.

Optimum investigations indicate that a given payload can be carried into the orbit with less take-off weight, if the number of stages of the satellite vehicle exceeds the minimum of three. The exact figure for the optimum number depends upon the choice of propellants and the mass ratios considered realistic for the individual stages. Most authors believe that an optimum satellite vehicle should have four or five stages, and further refinements such as jettisoning of power plants and tanks have been suggested.

However, if we think of using the satellite vehicle for the preparation of an interplanetary voyage originating in the orbit, we must bear in mind that a great number of supply flights to the orbit will be required. Inasmuch as the last stage can glide back to Earth, it may be used for repeated flights. It would greatly facilitate the supply operation, if the booster stages could likewise be salvaged and repeatedly used. Careful studies of this problem have convinced me that such booster recovery is definitely possible. If an expedient track of ascent is chosen, the burnt-out boosters can be decelerated by means of steel-mesh brake parachutes in such manner that the terminal rate of descent does not exceed 150 or 200 feet per second. Since empty boosters have enough buoyancy to float, they should be landed in the ocean, and their rate of descent at the moment of ditching could be reduced to virtually zero, if the parachute descent were decelerated by means of powder rockets ignited by a proximity fuse immediately before impact. In this manner, the boosters would very gently take to the water and not suffer any damage. It would appear possible either to take the floating boosters aboard a salvage boat or to tow them back to the launching site.

The greater the number of stages of the satellite vehicle, the more involved this booster recovery problem will become. Not only that more boosters must

be salvaged after each flight, but the last booster will land so far from the take-off site that its shipment back to the base will delay the entire supply operation to the orbit. Therefore, the question as to how many stages should be chosen for the satellite vehicle should not be investigated exclusively from the aspect of minimum take-off weight for the individual ship, but also in the light of the master plan for a supply operation such as is required for the preparation of an interplanetary voyage starting from the satellite orbit.

Let me return to the winged descent of the satellite vehicle's last stage. This descent raises a number of interesting questions.

What altitude should be chosen for the perigee of the landing ellipse, in order to convert the elliptical approach into a glide-path? The air density at this altitude should be sufficient for generating enough downward lift to prevent the last stage from receding from the Earth again on the second leg of the ellipse, and yet it should be small enough to avoid excessive skin temperatures during the initial phase of the glide through the atmosphere. I found that an altitude of the perigee in the order of 50 miles is expedient.

What skin temperatures will be encountered during this rapid glide? Despite the high altitudes at which the glide is performed, the heat influx into the ship's skin is very great. The only reasonable way of controlling skin temperatures appears to be the use of skin material that may safely be used at temperatures where re-radiation equals heat influx. Inasmuch as, according to Stefan-Boltzmann's law, the rate of skin radiation increases with the fourth power of the absolute temperature, skin temperatures well above 500° C must be allowed. It was found that the entire glide of the third stage from the satellite orbit can be performed in such manner that skin temperatures never exceed 730° C. Heat resistent steels are available, which can handle such temperatures.

One can always reduce the skin temperatures during the glide by applying a smaller wingloading, i.e., by equipping the last stage of the satellite vehicle with larger wings. These enable the last stage to perform the critical portion of the glide at higher altitudes where the heat influx is reduced on account of the lesser atmospheric density. The choice of the wingloading is also important in the matter of landing speed, in that the latter decreases with decreasing wingloading. If we choose a wing loading whereby the skin temperature during the glide does not exceed 730° C, the last stage of our satellite vehicle would have a landing speed of about 65 miles per hour, less than the touchdown speed of a conventional airliner.

For such a wingloading the length of the glide-path from the perigee of the landing ellipse to touchdown is about 14 000 miles, which is a little more than 50 percent of the circumference of the Earth. Inasmuch as the preceding free-coasting flight through the landing ellipse also leads half around the Earth, the last stage performs one full circumnavigation from the deceleration maneuver in the orbit to the touchdown. The flight time from orbit to landing would be roughly two hours.

Let us now suppose we had a reliable satellite vehicle. Would it really render possible the exploration of other planets?

During the past three years I spent my spare hours making a comprehensive study of an expedition to Mars, which is at present in the process of publication*.

The study deals with an expedition of 70 men, travelling in ten space ships from a satellite orbit around the Earth into a satellite orbit around Mars. Landing on Mars' surface is performed with three winged "landing boats", two of which are capable of returning to the space ships left circling in the circum-Martian orbit. Only seven of the ten space ships, with the original crew of 70, return to Earth. The expedition is prepared with the help of a fleet of 46 three-stage satellite vehicles. In 950 flights, these satellite rockets haul space ship components, propellants, landing boats, auxiliary equipment and crews to the "orbit of departure" where the space ships are assembled and whence the Mars fleet takes off.

The entire investigation is based on chemical propellants. In order to avoid the logistic problem involved in the use of large quantities of liquified gases, the calculations have been based on hydrazine (N_2H_4) for fuel and nitric acid (HNO_3) for oxidizer.

The three-stage satellite vehicles are the largest units required for the entire undertaking. They would be capable of delivering a payload of about 39 metric tons to the orbit in each of their flights. The overall length of the satellite ship would be about 200 feet, the maximum diameter 65 feet and the take-off weight 6400 metric tons. Both boosters can be recovered by combined parachute and rocket landing mechanisms, whereas the third stage would glide back with the help of its wings.

The design of the orbit-to-orbit ships can greatly benefit from the fact that they operate exclusively in empty space. They require no streamlining and not even a hull. In order to facilitate their hauling into the orbit, their spacious tanks could be made of collapsible fabric or plastic. These tanks could be freely suspended in an open lightweight structure. The stage principle, so essential for the satellite vehicles, could be abandoned. Instead, the empty propellant containers would simply be separated from the open ship structure after each power maneuver. Inasmuch as the ships start their voyage from an orbit, in which weight is completely balanced by centrifugal force, the thrust rating of their power plants may be limited to a fraction of the ship's initial weight. The entire round trip to the circum-Martian orbit could be conducted with a rocket power plant whose thrust rating does not exceed that of the satellite vehicle's last stage, and this same power plant may be used from the initial maneuver of departure down to the terminal maneuver of return to the orbit around the Earth.

It is evident, then, that all these factors greatly simplify the task of designing interplanetary rocket ships. We should remember, however, that such possibilities can only be fully exploited by a strict separation of the tasks of interplanetary ships from those of the satellite vehicles which must be designed for flights through the atmosphere and for ascent within the gravitational field of the Earth. Indeed, the design of an interplanetary orbit-to-orbit ship appears

* (Wernher v. Braun und F. L. Neher, „Menschen zwischen den Planeten" [Das Marsprojekt], Bechtle Verlag, Eßlingen a. N., Germany)

to be much less of a task than the development of a satellite vehicle. We may say, therefore, that the satellite vehicle is not only the first, but the decisive step toward interplanetary flight.

A flight to a circum-Martian orbit would not be complete if it were not climaxed by a descent to the surface of the Red Planet itself. The orbit-to-orbit ships, solely designed for use in empty space, are unsuited to this task. Our 70-men expedition needs special landing boats, which could descend from the circum-Martian orbit in very much the same manner as the last stage of the satellite vehicle returns from its orbit to the surface of the Earth. The design of such Mars Landing Boats is complicated by a number of factors, however.

(1) Whereas the last stage of a satellite vehicle would land with empty propellant containers, the landing boats would have to carry enough propellants down to Mars' surface to enable them to return to the orbit;

(2) The bottom density of the Martian atmosphere is only about one-twelfth of the sea-level density of the terrestrian atmosphere, and the lift produced by a wing of equal size and at equal landing speed would be correspondingly smaller. On the other hand, the gravity on Mars amounts to only 38 percent of that on Earth, and the lift actually required is reduced to that extent. In taking both these factors into account, it turns out that for the same landing speed, the wing area of a ship of a given mass landing on Mars must be four times as large as for a landing on Earth. In view of the beformentioned fact that a Mars Landing Boat must descend heavily loaded with propellants, it is obvious that it requires very large wings. Prior to the return of the boat into the circum-Martian orbit, these wings can be shed, of course. Considering Mars' weak gravitational field, the re-ascent can be easily performed with the one-stage rocket constituted by the boat's hull.

If we abandon one boat on Mars' surface and return the landing party to the orbit in the two remaining boats, we can fill more than a hundred tons of payload into the first boat, because it requires no propellants for the reascent. In this manner we can carry down to Mars' surface a load adequate to supply a landing party of about fifty people for more than a year.

How can we haul these heavy landing boats from the Earth into the circum-Martian orbit? Fully loaded with propellants, each of these boats would weigh about 200 tons!

Any space ship designed for the round trip between Earth and Mars must arrive in the circum-Martian orbit with a sufficient propellant supply left for the return voyage. The ones I investigated would still weigh a little over 400 tons after settling in that orbit. Therefore, all we have to do is to abandon those three orbit-to-orbit ships that carried the landing boats, after arrival in the Mars orbit, and perform the return voyage with the seven remaining craft. Over and above the landing boats, each of these one-way orbit-to-orbit ships could then haul about 200 tons of additional payload into the circum-Martian orbit.

Difficulties may arise in shipping a landing boat with its airplane hull peacemeal in the crowded cargo holds of the satellite vehicles, and in assembling it in the orbit of departure. It would, therefore, appear expedient to have

the landing boat fly to the orbit of departure under its own power. It will entirely be capable of doing this if we mount it on two standard boosters of the satellite vehicle, in lieu of the normal third stage.

It would exceed the scope of this paper to present you with a complete proof that all this is a real and serious possibility. For this proof I must refer to the publication mentioned before.

You may be interested in a tabular compilation of the results, however. For this reason I prepared four tables.

Table 1 shows the main data of the three-stage satellite vehicles.

Table 1

Three-Stage Satellite Vehicle

First Stage		
	Thrust	12800 tons
	Burning Time	84 sec
	Velocity at cut-off	2350 m/sec
Second Stage		
	Thrust	1600 tons
	Burning Time	124 sec
	Velocity at cut-off	6420 m/sec
Third Stage		
	Thrust	200 tons
	Burning Time (ascent)	73 sec
	Velocity at cut-off	8260 m/sec
Total Ship		
	Length	200 ft
	Diameter	65 ft
	Take-off weight	6400 tons
	Propellant supply	5583 tons
	Payload (hauled to orbit)	39.4 tons
	Landing speed (third stage)	65 mi/h

Principal data of the orbit-to-orbit ships are compiled in Slide 2. The figures apply to the seven ships designed for the round trip involving the following four power maneuvers:

(1) Departure from orbit around Earth.
(2) Induction into orbit around Mars.
(3) Departure from orbit around Mars.
(4) Induction into orbit around Earth.

Table 2

Orbit-to-Orbit Ship

Thrust	200 tons
Total propellant supply	3662.5 tons
Total length	134 feet
Diameter	95 feet

Maneuver 1		
	Initial weight	3720 tons
	Terminal weight	906 tons
	Burning time	3965 sec
Maneuver 2		
	Initial weight	902 tons
	Terminal weight	410 tons
	Burning time	658 sec
Maneuver 3		
	Initial weight	408 tons
	Terminal weight	186 tons
	Burning time	298 sec
Maneuver 4		
	Initial weight	185 tons
	Terminal weight	50.5 tons
	Burning time	163 sec

Table 3 shows the principal data of the Mars Landing Boats. The two boats designed for landing and re-ascent can each carry a payload of 12 tons down to Mars and 5 tons back to the circum-Martian orbit. The third boat, to be abandoned on Mars' surface, is capable of landing with a payload of 125 tons. This gives us a total payload of 149 tons available for the landing party. Aside from such vital necessities as food, oxygen and water, such payload may include ground vehicles suitable for land excursions on the Martian surface; inflatable rubber houses wherein the landing party can live without pressure suits; and similar luxuries. Luxury, incidentally, may be the wrong word, for you will agree that only with such elaborate facilities an extended stay and a successful exploration of a strange planet will be possible.

Table 3

Mars Landing Boat

Thrust	200 tons
Initial weight	200 tons
Landing weight	185 tons
Landing payload	
(one-way boat)	125 tons
(two other boats)	12 tons
Landing speed	120 mi/h
Take-off weight (re-ascent)	138 tons
Payload for re-ascent	5 tons
Burning time (re-ascent)	147 sec
Velocity at cut-off (re-ascent)	3700 m/sec

Slide 4, finally, compares the scope of such an expedition to Mars with the expenditures involved.

Table 4

Relation of Time and Weights of Propellants of an Expedition to the Planet Mars.

Number of participants	70
Total duration of voyage	2 years 239 days
Traveling time Earth-Mars	260 days
"Waiting time" in circum-Martian orbit	449 days
Hereof, Stay of landing party ca. 50 men on Mars' surface	ca. 400 days
Traveling time Mars-Earth	260 days
Total payload available in circum-Martian orbit	ca. 600 tons
Total payload available on Mars' surface	149 tons
Number of orbit-to-orbit ships	10
Number of Mars Landing Boats	3
Required number of Satellite-Vehicles	ca. 46
Required number of supply-flights	950
Time required for supply operation	ca. 8 months
Propellants required for supply operation	5,320,000 tons
Propellants required for interplanetary voyage	36,600 tons

At first glance, 5 million and 320 thousand tons of propellants appear to be a startling figure indeed. But let us take a second look. This is the cargo of 443 tankers with a capacity of 12000 tons each. According to official statistics, the Berlin Airlift consumed about one-tenth of this amount in high-octane aviation gasoline! And all this just because of a little misunderstanding between diplomats! Compared with the fuel consumption of wars, the requirements for an interplanetary expedition would indeed pale into insignificance.

Let us hope, therefore, that by the time mankind is ready to enter the "cosmic age", wars will be a thing of the past, and, instead of paying taxes for armament, people will be ready to foot the fuel bill for a voyage to our neighbors in space.